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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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with the Assistance of

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLIX, No. 1. 75TH YEAR. JANUARY, 1900

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Mechanical and Engineering Section.

INTRODUCTORY ADDRESS.

BY WILFRED LEWIS,
President of the Section.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Thursday, October 5th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

For seventy-five years the Franklin Institute has devoted itself assiduously to its well-known object, "the promotion of the mechanic arts," but in the performance of this great work it has realized at various times the advantages arising from the concentration of effort along certain lines within its broad and liberal scope.

The constant subdivision of scientific thought into branches whose bounds are more and more rigorously defined is an index of the progress of our age, not that there are more different kinds of science to be studied, but because the fields of research and investigation have so

expanded that the human mind is overwhelmed by the vastness of the whole, and individuals must be content to master thoroughly one small corner of a general division.

The Chemical, the Electrical and the Mining and Metallurgical Sections were consequently formed to meet the demand for more restricted bounds within which the specialists in these departments could carry on their work.

These sections are firmly established and their valuable services have been appropriately commemorated here to the honor of the Franklin Institute. They have records upon which they can look back with pride, and futures full of promise, but the work of the Mechanical and Engineering Section, which I have the honor to represent this evening, has only just begun.

About a year ago, it was suggested that a section of the Institute be organized which would appeal directly to the artisans, mechanicians, draughtsmen, designers and engineers, who form so large and important a part of our population. It was not intended to encroach upon the fields now occupied by the national and local engineering societies, whose members are for the most part engineers in active practice, but to form a society more democratic in its scope, which would welcome all who are interested in mechanical pursuits, regardless of their skill or attainments. Skilled and unskilled mechanics, novices and past masters in engineering were to have a common meeting-ground, where all might be heard, and it was hoped that in the meeting of earnest workers thus brought together, theorists would learn much to their advantage from the more practical men of action and manual skill, while the latter would be equally benefited by a deeper insight into the methods and principles of engineering.

The proposition to organize a section devoted in this way to the interests of the various mechanical pursuits at once met with favor, and the Board of Managers, at its stated meeting of November 9th, 1898, authorized the formation of a "Mechanical and Engineering Section." The inaugural meeting of the section thus authorized was held December 15th, under the leadership of Mr. James Christie,

Chairman of the Committee on Sectional Arrangements, and Chief Engineer of the Pencoyd Iron Works, which has so recently astonished the world by its successful competition with England for the construction of the Atbara Bridge in Egypt. Under his guidance the section sprang at once into active life and work, and there are now enrolled upon its list of members 188 active men, as the nucleus of an organization which cannot fail to be a power for good in this and other communities.

Although not at once a large society, our numbers are, nevertheless, encouraging as a part of the Institute, embracing as it does only 2,000 members, from which we must draw recruits, and we confidently hope to grow as the advantages of membership become more generally known.

To become a member of any section, one must be a member of the Institute, in good standing, and to be such a member it is only necessary to pay the small annual dues, in return for which such abundant returns may be enjoyed.

But it is my purpose to deal more particularly with the work of the section to which this evening is devoted, and to lay before you our special claims to consideration. Every industrial establishment in the city should be interested in our success, and our members would be counted by thousands and tens of thousands if the vast army of workers could be made to realize the helpfulness of mutual education by actual contact with fellow-workers in the same field of interest.

At the inaugural meeting, a code of rules was adopted, similar to those in force in the other sections. The selection of subjects for discussion was placed in the hands of a committee on information, who decided to devote the first stated meeting to Personal Reminiscences of Changes in Machine Design and Shop Practice. This proved to be an almost inexhaustible subject, and much interesting and entertaining information was elicited, some of the members going back fifty years, to the time when railroads and steamboats were in their first stages of development. Since then we have taken up the following subjects, the discussions of which have been reported in the *Journal:* "Travel-

ling Cranes," "The Mechanical Applications of Compressed Air," "The Construction, Operation and Maintenance of Pumping Machinery," and "Hydraulic Transmission, Valves and Packing."

In addition to the regular meetings, at which the above subjects were considered, a special meeting was called in February, to hear an address by Prof. Wm. S. Aldrich, on the U.S. Repair Ship "Vulcan," which played so important a part in the recent war with Spain. Prof. Aldrich was the Engineer-in-Charge on this remarkable vessel, and his lecture, amply illustrated by lantern slides, was full of interest.

The inestimable value of facilities for repairs at sea was clearly demonstrated, and in this was seen the immense latent strength of American forethought and mechanical genius. All honor to the men behind the guns, but they are powerless unless behind them stand the mechanics and the engineers who furnish the munitions of war with which swift and terrible execution can be accomplished. We have shown to the world our undaunted valor, energy and power to destroy, and we are now showing in a greater degree our power to build. Construction, rather than destruction, is the gauge of our real strength, and to none does the nation owe its supremacy more than to its mechanics whom the Franklin Institute has fostered and encouraged for seventy-five years.

But it is not for me to speak of the history of this noble institution, which has been aptly styled a "democratic learned society," and it would be presumptuous to make such an attempt in the presence of one who has been so long identified with its achievements—an engineer of international reputation, who has honored the Institute by his devoted service, and who has been honored in return by the highest office it could bestow—one who has labored for the enlightenment and prosperity of mankind like a true disciple of the immortal Franklin, and whose latest work has put Niagara in chains to serve our needs with the vast power that would otherwise be squandered. It is hardly necessary for me to introduce Dr. Coleman Sellers, who will now address you on "The Progress of the Mechanical Arts in three-quarters of a Century."

THE PROGRESS OF THE MECHANICAL ARTS IN THREE-QUARTERS OF A CENTURY.

BY COLEMAN SELLERS, E.D.,
Professor of Mechanics, Franklin Institute.

[An Address delivered in Convention Hall, National Export Exposition, Thursday, October 5th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Mr. President, Members of the Mechanical Section of the Franklin Institute, Ladies and Gentlemen:

I have listened with interest to the remarks of the President of this section, Mr. Wilfred Lewis, in regard to the advantages which have resulted from the formation of the several sections within the society, by which those members forming the respective sections can associate and effect an exchange of opinions on matters of common interest, apart from the regular meetings of the society at large.

In looking back to the time when the Franklin Institute celebrated the first half-century of its life, I recall the speakers on that occasion, and regret exceedingly that some are unable to take part in the present celebration. I had the honor at that time to be President of the Institute and presided at the meeting held in Musical Fund Hall. Among the speakers was Mr. Frederick Fraley, who delivered the historical address, he being one of the two survivors of the original founders of the Institute. Mr. Fraley is still with us, and is now the only survivor of those few men who had the good of the mechanic and craftsman at heart when they established what has proved to be among the most successful in its practical results of all institutes of the kind in the world. I regret that the condition of Mr. Fraley's health prevents him from being able to address you at this time, but I know that in heart he is with us, as he has been for the past three-quarters of a century.

The scope of the subject upon which I have been asked to address you merits careful preparation in order to pre-

sent it in a sufficiently comprehensive shape for the limits of a single address. I regret extremely that I have not had an opportunity for such preparation, and can offer, therefore, some informal remarks only, covering a few recollections and observations on the progress of the mechanic arts during the past seventy-five years. The records of the Franklin Institute are the records of much of the progress made during the whole of this time, and in the volumes of its *Journal* you will find abundant evidence of the good work of the earnest mechanics, engineers and teachers who have come together for mutual benefit and in the interest of this society. You will find no better place to note the progress of the mechanic arts than in the account of the work of these citizens of a great manufacturing city in the reports of the committees of the Franklin Institute, and especially the Committee on Science and the Arts, which for many years performed gratuitously what is now largely confided to paid experts. These men did this work of the Institute, and are still doing it, for the common good, without any expectation of other reward than the satisfaction of unselfish interest in mechanical progress.

The greatest advance in mechanics has been manifested since the advent of the locomotive. It so happens that the birth of the modern railroad system is coincident with my own birth. At that time the first railroad was put into operation in England, which development, taken in connection with the advent of the steamboat which preceded it, was certainly the exciting cause of the great industrial advance that has since been made. Previous to 1827 wooden rails had been laid to form roads over which ore was hauled from the mines, and coal was transported in the same manner by animal traction to better advantage than over common roads. Oliver Evans in our own country, and other engineers abroad, had conceived the idea of the high-pressure steam engine, and, with the full understanding of its value, a practical traction engine to use on roads, was one of the first examples of its application. It was after the invention of the road engine that the locomotive upon rails became possible.

The traction engine applied to the railroad was the basis of our present wonderful system of inland intercommunication, and its development has given an impetus to all trades. In fact, the wants of the railroads taken alone would have been sufficient incentive for what has since been done in the mechanic arts, engaging, as it has, the attention of engineers to produce the labor-saving tools required for the improvement and preservation of the railroads and equipment, including the great iron and steel works that supply the rails, bridges and buildings.

Special machinery has been constantly needed to render possible such industries as iron ship-building, bridge and structural work, and the appliances which have been introduced in place of hand labor throughout the industrial world.

The progress of the single industry of machine tool building has, therefore, a most important bearing on this subject, and traced through the many stages of its rapid growth, the development of this one industry would be sufficient to illustrate the progress in mechanic arts during the period in question, and especially what has been accomplished in this country.

The important relation which tools and implements bear to the mechanic arts and, in fact, to all arts and crafts, forms the subject of an interesting tradition which was published in the *Journal of the Institute* by the late Mr. Joseph Harrison, Jr. In his home at Philadelphia he exhibited a painting by Schusselle representing a blacksmith seated at the right hand of King Solomon's throne in his great temple, to illustrate a hypothecal event during the feast given in Jerusalem at the completion of the edifice. To this feast had been bidden the various artisans who had been engaged upon the construction and decoration of the building, those who had helped to shape the gold and silver and carve the ivory and weave the costly hangings that decorated its walls. There also came, unbidden and unrecognized, the swarthy smith, who, forcing his way through the courtiers and the guard to the throne of the king, claimed recognition as the one man to whom was due the creation

of the entire work, for it was he who had forged the tools without which the other artisans could have done nothing. The wise king, recognizing the justice of the claim, gave to the smith the seat of honor.

Antedating the smith of King Solomon's day and the mechanics of all times, the progress of civilization can be traced by the study of the implements used in the daily life of different races of man, and prominent in the progress of the mechanic arts must be counted the tools with which work has been accomplished.

As one instance of progress from primitive methods during the period under consideration, it may be of interest to refer to the construction of one of the first large engines that were built for the city water works in Philadelphia. There is probably no one present who can recall the fact from actual memory, but where our Public Buildings now stand there was once a smaller structure, on top of which was a tank into which water was pumped, and this water was distributed through the then small city below Broad Street by means of wooden pipes of comparatively small size. The engine used in this work was, I believe, of the Oliver Evans type of high-pressure engine, the cylinder of which was cast in New Jersey. The boring bar used in boring out the cylinder was of the crudest character, operated by hand by means of levers attached to it, so that men walking around the cylinder could propel the cutting tools, and gradually force the cutters on the boring bar, through the cylinder, until it had been turned out approximately true. After that the inner surface had to be filed to a sufficient degree of smoothness. Probably a month was consumed in this operation of boring the cylinder. As I shall take occasion to mention, the subsequent improvements in machine tools have changed the process of cylinder boring from an effort of days to the work of a few hours.

It may be of interest also to note that when the engines were erected and the boilers put in their place at this Center Square Station, the latter were found upon test to be insufficient for their purpose. Oliver Evans had specified

the length of the grate bars and the width of the furnace to be used, as also the length of the boilers, which were of the plain cylinder type, but the wise men of the city government believed that they could do better by making the boilers much longer than he had suggested, and they were so constructed. Upon their failure to do the work, Oliver Evans, who was in New York, was sent for in haste to correct the difficulty. His message to those in charge, enforced by his presence afterwards, was that they must cut off 10 feet from the length of each boiler. This seemed a strange proceeding, but he soon explained to them that the extra length which they had added to his prescribed dimensions was acting as a condenser to re-convert steam into water, inasmuch as the heat of the furnace could not extend the whole length of the boilers as they had been built. Upon cutting the boilers down to their proper size so the heat could extend over their whole fire surface, they proved sufficient for their work, and continued to operate as long as this primitive water plant was in existence. I have this story from those who were living at the time.

I hope I may be pardoned for alluding here to some events in my own experience as a mechanic in order to justify my authority as a historian. From earliest childhood my interest has been led in the direction of the mechanic arts. My first knowledge of physics came from my father, through his instructions and experiments for my benefit before I had fairly passed out of the stage of infancy, for I was but seven years old when I lost so able a teacher. As a schoolboy most of my holidays were spent in his machine works at Cardington, near Philadelphia, where I had abundant opportunity to not only know what was being done at that time, but I had from my seniors the history of what had immediately preceded my personal observation.

My acquaintance with the rapid advance in the railroads of America, and in the motive power on the roads, dates from the time when the building of locomotives was undertaken in my father's shops, immediately after Matthew Baldwin had started his works in Philadelphia. When I was 19 years of age I accepted service as draughtsman

in a rolling mill in Cincinnati, where rails were being made for the roads then projected through the Western States. The rails used at that time, which were called strap rails, were flat bars of iron about 3 x 1¼ inches in section, with oval depressions rolled into the face to receive the head of the spikes driven through the rail to fasten it to string pieces of wood. They were punched at each one of these depressions, which marked the location of the spike hole. At that time the most common accident on the railroads was one unknown now, namely, "snake heads," as they were called, when the strap rails, by the action of the wheels upon them, would curl up, drawing the spikes from the wood, and often piercing the bottom of the car, and not infrequently killing or injuring passengers.

After my experience in the rolling mill, where I acquired a knowledge of the wants of the railroads, I was engaged for seven years in locomotive building, first in constructing engines for the Panama Railroad, in connection with one of my brothers who was the inventor of a locomotive for ascending inclined planes. The late John C. Trautwine was the Consulting Engineer of the Panama Railroad, and it was on his recommendation that these engines were ordered, in the belief that some heavy inclines would have to be overcome in passing from the Atlantic to the Pacific Ocean at Panama, although these inclines were avoided, and the engines eventually used in the construction work merely.

Subsequently I entered the locomotive works of Niles & Co., of Cincinnati, as foreman for five years until 1857, when I accepted service as Chief Engineer for William Sellers & Co., of Philadelphia, then, as now, engaged in building machine tools. Thirty years' active experience in machine tool building enables me to speak from a full knowledge of this industry and what machine tools have done for the advance of the mechanic arts. When engaged in locomotive building in Cincinnati, I introduced a number of improved methods, but was hampered continually for the want of machine tools powerful enough to do the work as I desired it done, as well as for the want of special tools

not then available. At that time in the Eastern cities certain machine tools were being built with success and were doing far better work than it was then possible with tools built in a branch of the locomotive works where I was engaged. The firm of Niles & Co. had, however, some reputation even then as builders of machine tools and sugar machinery, but it was not until the retirement of the original founders of the house that the works became devoted wholly to the machine tool business. At the time I speak of, slotters, horizontal boring machines and lathes of various kinds and quality were built in America after the introduction of the planing machine, the first one of which was probably introduced into the city of Philadelphia some time about 1830.

The early machine tools were of the crudest workmanship, and most of the lathes were made partly of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this century, and the formation of the tools themselves and much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood to metal, architectural shapes and ornamentation were considered desirable to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. The same might be said of locomotives, which almost up to the sixties were elaborately decorated with paint, polished brass and scroll work. England gave us the first good machine tools, and set the example which has tended to simplicity in design. To that country we owe much that is valuable, not only in the direction of self-acting machine tools, but also in the various appliances for improving the character and quality of work to be accomplished. Thus, Sir Joseph Whitworth, one of the earliest makers of superior machine tools in England, aimed at utility and not ornamentation in the improvement of his products. It was he who introduced surface plates for producing other plane surfaces by means of the scraper; that is to say, after a surface had been made

comparatively true on the planing machine, it had yet to be brought to a commercially true plane by a process of scraping off the higher projections, until, when tested by one of the Whitworth surface plates, it seemed to touch at intervals of not more than ¼ inch.

After scraping had come to be recognized as the only means of making true plane surfaces, there followed, unfortunately, a form of deception that exists, I am sorry to say, not only in America, but still more prominently in some of the copies of American machine tools produced abroad, namely, the practice of scraping the surface without any special regard to the purpose for which the operation is intended, but rather to give it the appearance of having been carefully fitted, and the surface so produced was very aptly called by the late Mr. William B. Bement, of Philadelphia, "bedquilt scraping." The parts touched by the scraper in this imitation work are very often not irregular in design, but constitute a set figure or pattern which cannot deceive the eye of those familiar with good work.

Long before the time of the International Exhibition of 1851, America had begun to take her place in machine tool building, under a clearly distinct line of thought that was for a long time not appreciated in other countries. When visiting England, in 1884, I was shown a copy of an American planer adapted to planing the stub ends of connecting rods for locomotives, there being two sets of uprights and two cross-heads with four tool-holders adjustable in position to enable both ends of two connecting rods to be planed simultaneously. The American tool from which the idea was taken has its cross-heads facing one another, and the table is speeded to run back and forth at the same rate of cut. By this means the machine is made to take a cut at each forward and backward movement of the table. The English machine had its tool-holders facing in one direction, and all four cuts were taken at one and the same time only when the table was running forward, no work being done on the back stroke. The power of the American machine was therefore double that of its English copy, all other things being equal, and the maker was astonished when this was pointed out to him.

This one example shows how difficult it is to copy the machinery of another country if the copyist does not grasp the controlling idea of the mind that gave life to the original. Instances of this are found in many other directions where American contrivances, having obtained a world-wide reputation, are less efficient in the foreign copy than in the original production.

The planing machine is an invention well within my own experience. In the beginning it had the platen, upon which the work is fixed, dragged backwards and forwards by a chain. The first planer that William Sellers & Co. purchased and put into use was one of this chain pattern, and one was introduced in my father's shops when he undertook to build a locomotive in 1834. At the time of the Vienna Exposition, where machine tools from Philadelphia were exhibited, the engineers sent by the British Government to Vienna to note the progress that was being made noticed the broad feed cut on all the planing machines, lathes and tools that came from all parts of America, and remarked upon it as "producing good effect," as "looking well," etc., as if it were for appearance only, not knowing that it was a principle that had been established in America, thoroughly understood not only by the managers of the works, but by workmen all over this country, and universally adopted as necessary to good work.

I have already referred to the slow process of boring cylinders for pumping engines. When the early locomotives were built, for example, in the Niles Works, in 1856, the boring of the cylinders was done on a 36-inch lathe with a horizontal boring bar, and without any knowledge as to the theory of boring in order to produce the best results. It always took two days to bore the cylinder of a locomotive of the size in use at that time, and I think the largest cylinders were not over 15 inches in diameter. In Philadelphia, when Baldwin's had advanced to a very large establishment, they still bored the locomotive cylinders in the same way. It was not until shortly before the Centennial Exhibition of 1876 that attention was turned towards the utilization of a theory that had obtained in

limited practice some years before as to the improvement in boring metals, the idea being that the quickest and best work can be done in boring by making the roughing cut with a fine feed, removing as much metal as possible by depth of cut, and making the finishing cut with a very broad feed but light cut that would let the cutter pass through the hole to be bored as quickly as possible so as not to wear the cutting edge in passage. That principle was first introduced when Mr. Asa Whitney, of this city, discovered that chilled cast-iron car wheels could be made to compete with the best wrought-iron ones and do a greater mileage. If the wheels cast in an iron mould were not allowed to cool naturally, but taken red hot from the chill, were put into the annealing furnaces and brought up to a heat a little below the melting point, and then allowed slowly to cool, they were found to be free from all internal strains, while wheels taken red hot from the mould would burst into three or four pieces in cooling, showing that there was violent internal strain in metal cast in that way under the tension of the heavy chill on the outside of the tread of the rim. The problem of boring chilled wheels was solved by taking advantage of the fine roughing cut and coarse finishing feed. Mr. Whitney desired to have wheels made interchangeable in their fit on the standard axles, so that when a wheel was fitted on an axle at a workshop in Philadelphia, another wheel could be furnished to fit that same axle at any future time, and just as well as the first one.

When the late Mr. Hudson had charge of the Rogers' Locomotive Works he applied to the firm of William Sellers & Co., to have a special locomotive cylinder boring machine designed and built, saying that he had seen a boring machine designed by Mr. Grant, of the Grant Locomotive Works, capable of boring a 19-inch cylinder in nine hours. The matter was referred to me, and when I came to calculate the theoretical time required for boring a cylinder of the size named, on the supposition that the speed of 16 feet per minute might be used in making the cuts, with a fine feed and a deep cut for the roughing cut, and a shallow cut and a much wider feed for the finishing cut, I found that the

estimated time amounted in all to only three hours, and named three and a half hours as not only possible, but what might be guaranteed as the productive output of such a machine. An order was given for this machine, it being understood that it was not only to bore the cylinders, but to counterbore the ends for the clearance of the piston, to cut off the sinking head and face up the flanges at each end of the cylinder. When completed, the first test was made with a 19-inch cylinder of hard close metal. This was bored in three hours and twenty minutes, exclusive of the time of setting the cylinder, which was not much on account of the peculiar arrangement of the machine, and the facility with which the cylinder could be put in place for boring. In this case the cylinder stood still, while the boring bar travelled lengthwise, carrying the cutter head with it, and upon the two face plates of the driving heads of the machine were arranged automatic slide rests that faced off the flanges. In this design there was no guesswork, as the principle of fine feed and deep cut on roughing, with very coarse feed and shallow cut for finishing, was in common use in all operations of boring, turning and planing metals, with exact knowledge as to what result was obtainable when the possible speed of cut per minute had been predetermined for the hardness of the metal to be tooled.

Since the time when I first related the incident of the rod planer in a paper published by me in the *Engineering Magazine*, in 1892, even this tool, useful as it is, has been superseded almost wholly in locomotive works by improved milling machines. It is not my province to detail step by step the advance that has been made in machine tool building, but, as stated at the outset, I wish to make this industry illustrate the advance in the mechanic arts, and in connection with it I must call attention to the relative condition of the skilled workmen in America and in other countries. We owe much of our progress to our common school system, to our freedom from precedent and to our just patent laws. I do not wish in the slightest degree to decry what has been done abroad, for I myself have been a close stu-

dent of the progress of the mechanic arts the world over, and have been only too glad to recognize and avail myself of all that is good and worth adopting, assuming at the same time that improvement is possible and absolutely necessary in many cases to adapt the machinery designed abroad to the conditions that obtain in American workshops. The tendency to standardize everything is peculiar to this country. Builders of locomotives in America adopt standard sizes and types of locomotives, and are thus able to manufacture such to great advantage. Railroads in America are willing to take from the builders what has been shown to be good and effective, and when the same kind of machine is to be duplicated many times, the maker can afford to invest heavily in special gauges and special tools that decrease the amount of manual skill required in laying out the work or working to drawings. The first time a piece of work is done, whether it be small or large, simple or complex, more time is spent upon it than after the workmen have become familiar with its construction, and certainly more time than would be required after special appliances have been invented and made to cheapen the product, especially when the men are paid for their work according to the quality and quantity turned out, and not by a fixed wage per diem. I allude to this because I know it is the custom of foreign railroads to submit to builders in England and America specifications for engines that cannot compete in economy of construction with those that are built in quantities in the way that I have just mentioned. It is the recognition of this fact that is now opening the markets of Europe to American locomotives as they are built and as they are used in America. A celebrated builder of locomotives in England told me that the rules of the Board of Trade and Parliamentary regulations for the safety of the people crowded their locomotives with useless appliances. A close observer of railroad machinery, who is familiar with the principal railroads in the world, has stated that if a locomotive builder abroad is given a new problem, such as to construct a hill-climbing freight engine, or a goods engine as it is called abroad, or even an express passenger

engine for mountain districts, a completed machine may be the result that is a model of strength and durability, but inaccessible in the extreme when ordinary repairs are required. It is easier to take out the cylinders in an American engine and replace them with new ones than it is to reset the valves on the type in general use abroad, where the valve chests are crowded together under the smoke-stacks as though they would never require adjustment or resetting. The persistency evinced in adhering to the crank axle in English engines, in spite of its weakness, is one of the matters not understood in this country. Give accessibility to the valves, and ready access to all the parts, and the whole engine will be better cared for by those in charge of it.

It has been the scientific methods introduced by the managers of the railroads, aided by the skill and perfect equipment in their workshops, that have made those great railway systems what they now are. They must exercise the utmost caution in all that they undertake; every alteration or deviation from adopted standards involves so many pieces that must be changed. In regard to the simple matter of making brakeshoes for the cars, and boxes for axle journals, I know from my own experience that it was not until the introduction of machines for moulding these pieces accurately that the best results could be obtained and the parts made exact and perfectly interchangeable. Every invention, whether it be in the foundry or in the machine shop, is cumulative, and has its effect upon other trades, and through our ingenuity and progress we have now reached a point when the whole world looks to America for certain work which it seems cannot be done to equal advantage in other countries.

Dr. John Anderson, then in charge of the Woolwich Arsenal, England, was sent to this country to visit the Centennial Exhibition in 1876, and besides acting as one of the judges of the machine tool exhibit, he made an official report as British Commissioner to both houses of Parliament. Prominent in these reports there will be found one on "Machines and Tools for Working Metal, Wood and

Stone at the Philadelphia Exhibition," in which the following statement occurs:

"Great Britain certainly can claim the credit of having been the birthplace of modern machine tools, and has done wonders in raising the mechanical standard of perfection, and her influence for good in the advance of civilization thereby is incalculable; but when we consider the enormously greater area of the American continent, it is a matter of vast importance that tools have taken such a hold of the American mind, which will influence the civilization of the Western world for ages to come, and will exercise a powerful effect, not only on that continent, but on Australia, China and the world generally." This, therefore, has a profound significance which can scarcely be overrated. Again he said: "The display of machine tools made by the United States was so vast that only the more salient points can be noticed in a brief report. It showed certainly that the past century has not been passed in idleness, and, judging by the enormous stride made by them during the past few years, it showed that they have been intelligent students of the best European authorities. It is true to say, however, that the Americans, as a rule, are not copyists; the inventing of clever devices and tools for saving labor seems to be their natural forte, and worthy of the old stock, probably quickened by the peculiarly favorable circumstances under which they live. It was the display made in this section which most conspicuously brought out the enormous strength of America as a producing power. More than a hundred exhibitors had each a large exhibit that commanded the admiration of all who took the trouble to examine them in detail. In this vast array were machines for all purposes, small arms, ammunition, sewing machines, clocks, watches, and all the branches of machine-making and engineering, and almost all were finished in a style superior to that of any former exhibition."

In the engineering practice of the first quarter of this century, scientific methods did not obtain. There was little technical literature to help the designer, and the best results which have made American ingenuity appreciated the

world over were brought about through careful experiments and earnest effort on original lines. The history of the steam engine, so far as the American types are concerned, was clearly not the outcome of the books, for what is thus taught under the head of thermo-dynamics is really a description of what had been accomplished, rather than the cause of the development. The need of technical education was early felt, but the want was not supplied until the generosity of individuals rendered the foundation of technical schools possible. The Government cannot be looked upon to aid in such institutions in the United States as it can in England, yet up to 1884 in London there was no technical school in existence that in any way compared with those at Hoboken and Boston in this country, besides which engineering is now taught in our universities. At a dinner given to the members of the Institution of Civil Engineers, in 1884, Sir Lyon Playfair, in responding to the toast of "The Universities of Scotland," after those of England had already been discussed by able speakers, astonished his audience by refusing to speak to the toast directly, and entered a strong plea for technical education in England such as existed at that time in the United States. He said they should not look to Germany and France for the examples of technical schools, but across the Atlantic, where those speaking their own language had already put into practice what England had so long needed. While the speaker was doubtless correct as to the wants at that time in Great Britain, the technical school of South Kensington was then being organized, and the guilds of London had contributed freely toward its support. Good work had been done by this and other schools, and by the trade schools that have been established in various parts of England.

We are long past the period of empirical work. The steel makers and iron founders now depend upon metallurgists to guide them, while every well-equipped machine shop in the country must have its staff of educated men who are able to reinforce the practical knowledge of those engaged in manufacturing by exact mathematical methods

that in the early stages of our profession were limited to simple arithmetic.

As indicative of the necessity of education on the part of the working classes, I have known instances in which labor-saving machinery that was cheapening the output in a particular class of hardware, when introduced in America, into England, failed entirely and brought discredit to the member of the firm who had advised its purchase. A gentleman interested called upon me afterwards and solicited letters enabling him to visit some of the industrial establishments in the United States. Upon his return from these places he told me that all that had been said about the character of the work done by the machinery in question, not only had been confirmed, but that its merits had been underestimated. He said, however, that in his opinion, it was impossible to utilize it to advantage with the workmen in England, owing to trade prejudice and trades union regulations. What the peculiar conditions were I am unable to say, but what I wish particularly to impress upon my hearers in this respect is that in his opinion the difference in the character of our workmen and workmen of the same trades in England is wholly due to the better education of the Americans, who are fully two generations ahead of those abroad. It is perfectly evident that it is impossible to raise the standard of work by means of labor-saving machinery unless the workingmen themselves will see the advantage derived from their ability to do more and better work, and thereby obtain better wages. This is particularly the case when they are called upon in this country to operate machines that do not require constant attention, but where it is possible for one man to attend several machines and earn higher wages than he possibly could if compelled to stand idly watching a machine that required but a small portion of his time to operate. There would be no inducement to contrive automatic machinery unless those who use such machinery are able without prejudice to take advantage of the saving in labor attainable thereby.

Ship-building all over the world, since the first iron vessels were launched, shows by the constantly improved out-

put the wonderful progress in scientific knowledge, and in manual as well as technical skill. The great fighting machines for the ocean have been improved with astonishing rapidity. This year our own output in that line has for the first time been tested and found good, when handled by men of whom we as a nation may feel proud. The nations have been increasing the power of their fighting ships year by year, adding new improvements in machinery, new means of resisting attack from other ships, new guns and newer projectiles to pierce the new armor plate, and let us hope with decreasing opportunity to bring the results to actual test in battle. In our own recent experience, practice at great cost found our trained marine force better equipped for the operation of these fighting machines, and in the far East and in the West Indies our guns swept a maritime power out of existence with upon our part scarce the loss of a man.

In working iron and steel the introduction of the Whitworth forging press marked an important advance compared with the costly steam hammers, and hydraulic presses became absolutely essential in perfecting the American type of link and pin bridge construction. Some of the forgings required for the 5,000 horse-power dynamos needed by the Niagara Falls Power Company could not have been executed by means of any existing steam hammer in this country or elsewhere, and the Bethlehem Steel Company were the first to introduce this system of forging on a large scale. Forging by pressure in place of impact by hammers enables the force required to cause a given deformation of metal to be accomplished with the least expenditure of power and greater exactness, as was soon manifested in the readiness with which hollow shafts were produced. About 1893, the work at Niagara Falls called for steel rings of absolutely uniform density, having an outside diameter of 11 feet 4 inches, with a width on the face of approximately 50 inches, and a thickness of over 5 inches, which necessitated the use of a press of greater capacity than any heretofore erected. The press at Bethlehem, combined with the Whitworth system of compressed steel ingots, was taxed to its utmost to make what

was needed in this case. It is interesting to note that this work was the first product of machinery introduced mainly to furnish armor plates and the massive steel forgings needed for our modern ships of war.

The plant of the Niagara Falls Power Company offers evidence enough of the remarkable progress that has been made, not only in the mechanic arts, but in the high scientific ability required to design machines that had no precedent in size or in exact requirements as expressed in the specifications predetermining each requirement as to the results to be accomplished. Thus the designers of the dynamos were called upon to guarantee an output from each unit of power with so high an efficiency that all the magnetic and electric losses in the machine would not amount to over 2½ per cent. This requirement was fulfilled, and when subsequent machines were installed, the result was even more favorable than in the first instance. The final result is the crucial test of all progress, and certainly we have in those of our industries which require mechanical skill sufficient evidence of the marvellous progress that has been achieved during the past seventy-five years.

As I have taken occasion to mention the work at Niagara Falls, which has engaged so much of my attention, it may interest those who are not familiar with the results of this undertaking to hear something further in regard to it. At Niagara Falls we had for the first time to construct a tunnel that would be adapted as a tail race to the development of 100,000 horse-power. The International Niagara Commission had decided that 5,000 horse-power was to be the unit, and the plant was accordingly laid out on this basis. It was assumed that water-wheels could be made of that capacity and could be placed 150 feet below the level of the dynamos to be operated, where, as one of the Commissioners suggested, the length of shaft would be about the same as between the propeller and engines of an ocean steamship. In the practical solution of this problem we were obliged to have similar thrust bearings to guide the shaft, but the construction of the turbines is such that the water under the upper wheel of the two in the case is made to support

the whole mass of about 160,000 pounds. The dynamo at the upper end of the shaft, therefore, practically spins on a cushion of water with only a pressure of 3,000 more or less on the thrust bearing rings, according to the variations in the velocity as the power developed is increased or decreased.

It is too large a subject to permit me to refer in detail to all of the work that had to be done at Niagara Falls, but I want to say that, while our constant effort has been to interest the manufacturers of machinery to make designs that they could guarantee, a great deal of designing has been necessary by the engineers of the company, most of which was experimental, and that no failures should have been experienced is most satisfactory, when I realize how little precedent we had to guide us, and the risk attending the solution of the problem as it was presented to me.

The first three turbines that were installed in accordance with the design of the builders had to be materially altered, and I have introduced improvements of my own invention to enhance their efficiency as far as the shaft transmission is concerned. These modifications were made in the five units that were subsequently installed, and without any change in the water-wheels, the efficiency was increased so that they delivered 5,500 electrical horse-power each, instead of 5,300 horse-power, which was the output before the changes were made.

As now constructed, all the electrical and magnetic losses in each of the dynamos aggregate but 2½ per cent., and you can judge what the efficiency of the water-wheels must be when those which, at 75 per cent. efficiency, would give 5,300 horse-power, are now driving dynamos that deliver 5,500 horse-power without any changes in the wheel, but only such alterations in seemingly immaterial parts as the design of the connection between the water-wheels and the dynamos.

As regards the utilization of the power being developed at Niagara Falls, it may interest you to note that we hope shortly to have ten dynamos running, each of 5,000 horse-

power nominal capacity, but actually capable of delivering over 5,000 horse-power each.

The first industry established in connection with the plant was a paper company, which required 7,200 horse-power, but it installed its own wheels on land of the Power Company, and utilized the latter's tunnel and canal facilities. Next followed the Pittsburg Reduction Company, which takes 8,550 electrical horse-power for the manufacture of aluminum. The Carborundum Company, for making abrasives, takes 1,030 electrical horse-power. The Union Carbide Company, 5,000 electrical horse-power, for the manufacture of carbide of calcium. The Niagara Electro-Chemical Company, making peroxide of sodium, that is, metallic sodium, takes 400 electrical horse-power. These and other works now in operation or being installed will utilize, possibly by the first of next year, a total of 41,000 horse-power. Most of these establishments are electro-chemical or metallurgical in their processes, and have sprung into existence with the development of hydro-electric power, although they are based upon principles which were discovered years ago. The metal sodium, for example, is made commercially by practically the same process as was employed by Sir Humphrey Davy when he first began experimenting with the galvanic battery for the reduction of metals. The alternating current that has been adopted in the machines that generate this electricity is the alternating current as studied by Michael Faraday. The change in the potential from 2,200 volts at the machine to 11,000 volts in transmission is effected by the transformers that were discovered by Faraday, and were formerly used chiefly in Ruhmkorff coils and other philosophical instruments. The principle as known then became useful for lighting purposes when the alternating current took its place in the lighting of cities.

In the problem presented at Niagara Falls we had to provide for direct current to operate railroads and for electro-metallurgical purposes. This power is developed as alternating current, and transformed from 2-phase into 3-

phase by an invention of Mr. C. F. Scott, of the Westinghouse Company.

It is a noteworthy fact that, since the first wheels were started in 1895, there have been no stoppages of more than an hour or two at the most. The plant has been in operation night and day, carrying on processes that permit of no interruption on account of the loss which would result.

I regret that I cannot discuss this subject at greater length, for the machinery and appliances installed at Niagara Falls, as well as the industries which have resulted from the development, have made the enterprise one of the important achievements of the period we have under consideration.

Reviewing the century's progress, one cannot but be impressed with the tendency to specialize all industries. It has been truly said that jobbing shops are and always will be a necessity, but that manufacturing establishments will lead in the march of improvement. Trades are becoming more diversified, and time, talent and capital are being expended upon individual machines and appliances as special which were formerly but a part of the output of single establishments. To this concentration of the best thought upon special branches of all industries we may attribute much of the progress in the mechanic arts made during the past seventy-five years, which has opened the markets of the world to the products of our industry. The influence of the Franklin Institute has played no small part in this progress, and as one long identified with its work, I extend my greeting to its members, hoping they will continue to advance the usefulness of an institution which worthily bears the name of one of the greatest philosophers that America, and the world, has produced.

Stated Meeting, held Thursday, November 9, 1899.

THE PRESSING OF STEEL; WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION.

BY HENRIK V. LOSS, M.E.

(Concluded from vol. cxlviii, p. 473.)

THE THIRD SYSTEM.

When considering the system of closed dies, these latter can be divided into three divisions or methods of application, namely:

(1) All dies to be fixed and stationary, having only the upsetting plunger movable.

(2) The surrounding dies to be partly movable and partly stationary.

(3) The surrounding dies to be all movable.

In the early history of upsetting materials, the first method was the one generally used, and it has been quite commonly adopted even up till to-day. Its great trouble lies in the fact that the necessary power to accomplish a certain work is very excessive, with a correspondingly heavy wear and tear of the dies. This necessary power is especially demanded at the end of the stroke when the dies are to be filled at some point farthermost away from the upsetting plunger. When upsetting rounds on square or round bars, it is a well-known fact that the power necessary to form a good neck is very great. In all upsetting it is a law that the material will flow *near the moving parts*, which, with this method, means near the moving plunger, and the further any stationary part is away from this moving plunger, the slower is the material to flow at this point; and the more power does it naturally take to fill the dies at this remote place. If, during the upsetting of a bar by this method, the latter is taken out of the die with the stroke half done, it will be seen that the metal is heavily upset near the plunger, but also that very little work has been done at the neck. Hence, a system of dies based upon this first division requires a maximum amount of power to accomplish a given work. (See *Fig. 8.*)

There is one application of this method which is in general use to-day—to be sure with some additional modified requirements—and represents a case where any other system would appear to be impossible, namely, the operation of riveting. The stationary dies are represented by the plates to be joined together, but the rivet hole must be filled up. An additional requirement lies in the demand for a well-filled good rivet head; but the hardest work is, after all, to fill the hole.

Fig. 9 represents indicator cards of $\frac{3}{4}$- and $\frac{7}{8}$-inch rivets. As clearly seen, hardly any work is done during the early part of the stroke, while at the finish the pressure rises very fast. The cards were taken on bridge work, and the results in figures, as given below, represent the necessary powers for

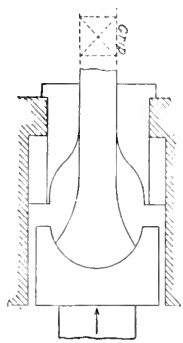


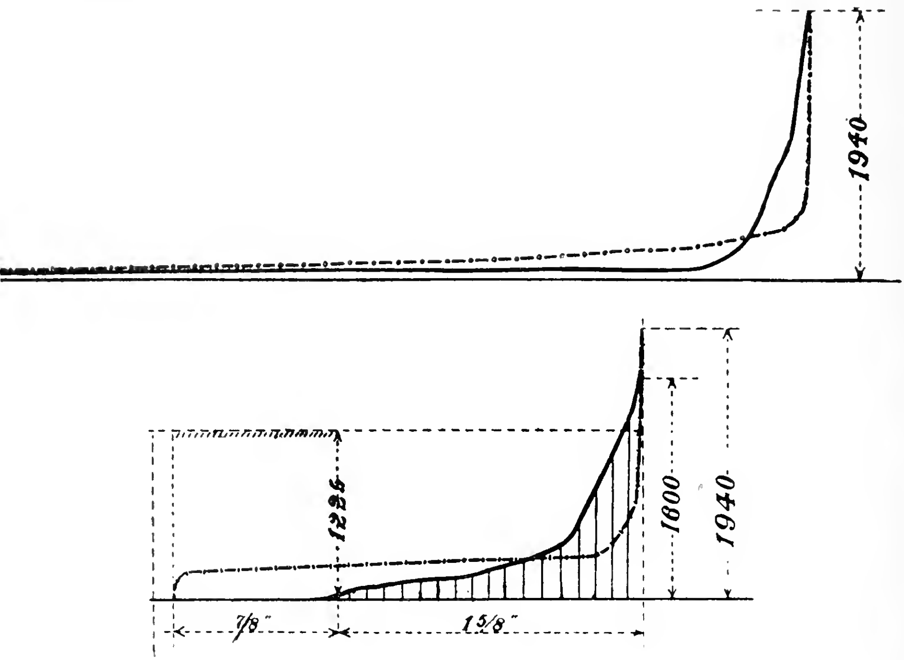
FIG. 8.

rivets of great lengths and only fairly matches holes. The total thickness of plates corresponding to the above cards was $1\frac{1}{2}$ inches or more. It is the sliding of the material against the more or less rough surfaces far away from the die holder which requires the great power used in bridge riveting, as compared to boiler work. The average results from a series of cards were as follows:

The power necessary to complete the heads on $\frac{3}{4}$-inch and $\frac{7}{8}$-inch rivets is about 60 to 70 tons, when working on such grips as mentioned above.

The necessary energy in foot-pounds for $\frac{3}{4}$-inch rivets is 7,200, and for a $\frac{7}{8}$-inch rivet, 9,500, or as in the proportion to the squares of the diameters.

With the view of showing the vastly improved results which can be obtained with short rivets and well-reamed holes, I shall attach some data derived by Mr. Vauclain, superintendent of the Baldwin Locomotive Works, on boiler plates. They form part of a discussion delivered before the Engineers' Club of Philadelphia a few years ago, and are as follows:



⅞-inch rivet.
2⅜-inch material.
67 tons on rivet.
58 per cent. impact.
Acc., 1225.
2½-inch stroke.
22 per cent. efficiency.

FIG. 9.

The suitable pressures for well-fitted boiler work are: For ⅝-inch rivets, 25 tons; for ¾-inch, 33 tons; for ⅞-inch, 50 tons; for 1-inch, 66 tons; for 1⅛-inch, 75 tons; and for 1¼-inch, 100 tons.

Some experiments were made by the William Sellers Company, Inc., on the question of cold riveting, and the results were in part laid before the Engineers' Club of Phila-

delphia, through some notes presented to that body on November 18, 1894, by Mr. Wilfred Lewis. He estimates about 300,000 pounds per square inch of rivet section as being necessary to upset the rivet and form the head.

It is undoubtedly true that the last pressure is concentrated upon the rivet head, and that, hence, the diameter of head enters to some extent when having to decide the total amount of power necessary to drive a rivet. But as the standard of rivet heads does not vary very much between the different makers, it is thus possible to use the rivet diameters as a basis of computation. Again, the resistance existing along the circumference of the rivet hole, when filled, will certainly be transmitted through the body of the rivet back to the tool holder, independent of that part of the head which is outside of the rivet and forms the collar.

A summing up of this division means an early flow with comparatively small stresses, all concentrated near the moving plunger, this to be followed by rapidly-increasing resistances towards the end of the stroke, accompanied by a slow flow at the remote parts.

The next step represents the resistance to flow in dies which are partly movable and partly stationary. When entering upon the question of movable dies an entirely new feature is brought into play, namely, the upsetting or dragging tendency of the surfaces of the movable parts, outside of the plunger itself. The effect of this is naturally beneficial, especially so if the moving dies extend far towards the stationary neck, causing thus, at this remote point, a flow which means directly that much power saved (as compared to the absolutely stationary method) when the final squeeze or pinch is required. The methods of movable or partly movable dies can be applied to almost any form of upsetting, and the principles involved hold good for all; but, as a means of illustration, I shall simply show the results as derived in the upsetting of eye-bars for bridges. The neck dies are, of course, always stationary, the semicircular plunger being always movable, while the remaining top or bottom dies will vary according to the system applied. If they were stationary, the criticism of the first system has

shown the necessary power to be excessive, and the present practice discarded them long ago; but if they are arranged to be stationary on bottom and movable on top, the flow of metal can be best illustrated by *Fig. 10*, which shows the form of a bar half upset and removed from the machine. The plunger has upset the back part, while the moving top die has dragged the metal along and upset the neck. An indicator card showing the power necessary for this division is seen on *Fig. 11*.

More work is here done during the early process of the stroke as compared to what existed with the absolutely stationary dies, but even so the final maximum ordinates are very great in proportion to the earlier dimensions.

The summing up of this division means a more uniform flow throughout the stroke, followed by a tendency towards a more even distribution of pressures.

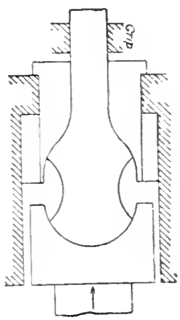


FIG. 10.

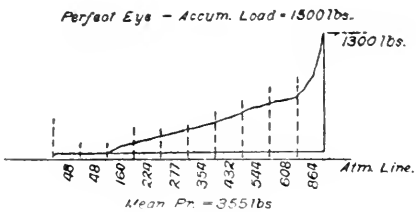


FIG. 11.

The third and last division, having all movable dies, represents an improvement upon the former two, inasmuch as the dragging tendency of the surrounding dies is here brought into play to the greatest possible extent. Hence the distribution of flow and pressures during any one stroke is more uniform than with the former methods. Again, let a bridge eye-bar illustrate this assertion. *Fig. 12* shows a bar partly upset, and the striking feature of *this sketch is the fact that the most remote parts from the plunger or header are the very first parts to upset.* An indicator card of this division is represented by *Fig. 13*, which also shows the great amount of work done during the early stages as compared to the two former methods.

Of course an allowance must be made in all upsetting cards for the extra amount of power necessary to form sharp edges—a power which always manifests itself at the end of the stroke, and which therefore gives somewhat of a false idea as to the general average resistance offered to the flow of the metal during the process.

This third division represents undoubtedly the ideal manner of upsetting materials, and while it has hitherto been applied only to a limited extent, I think such has been due entirely to a want of knowledge of the general flow of metals. The very fact that a result can be obtained by this construction with very much less power than by any other method—and also that offsets, far away from the upsetting plunger, can be filled with a degree of sharpness obtainable

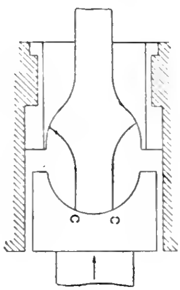


FIG. 12.

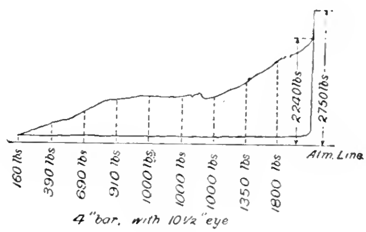


FIG. 13.

with no other system—ought to be enough to ensure its application.

One more important branch of this third system is represented by the process of flanging. The great majority of work of this kind, if heavy, is preferably done under the hydraulic press instead of under the hammer, and the application of flanged work is daily becoming more and more general, superseding riveted or cast sections wherever at all possible. The general work can be divided into two classes, namely, hot and cold flanging.

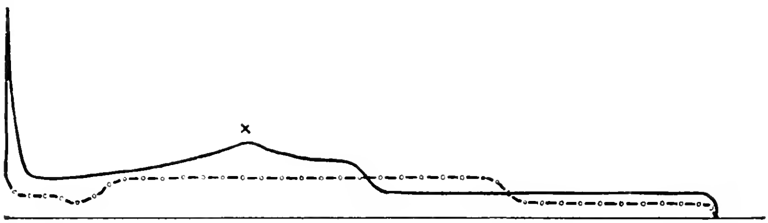
Cold flanging is generally confined to the thinner sizes, $\frac{5}{16}$ inch or $\frac{3}{8}$ inch being the greatest dimensions usually considered safe to be so treated. In all flanging the greatest effort is to edge the plate, that is, to sharpen the corners or bends and take out wrinkles.

Fig. 14 shows a typical indicator diagram of the flanging of the center part, about 17 feet in length, of a sill for a steel car. The material was $\frac{5}{16}$ inch in thickness, and the body of the sill was channel-shaped, having a flange at top and bottom.

A number of cards have been taken from cold work, and the average results can be summed up as follows:

Pressure per running inch to flange $\frac{1}{4}$ inch thick 70,000 pounds steel, 600 to 740 pounds.

Pressure per running inch to flange $\frac{5}{16}$ inch thick 70,000 pounds steel, 710 to 750 pounds.



Maximum pressure = 940 pounds per square inch.
Maximum pressure at × = 330 pounds per square inch.
To lift table = 120 pounds per square inch.
Maximum back pressure = 190 pounds per square inch.
Minimum back pressure = 90 pounds per square inch.

Cross-section of sill P. R. R. car—17 feet long.
$\frac{5}{16}$ inch thick. Two $3\frac{7}{8}$-inch flanges.

Scale: 1 inch = 752 pounds.

FIG. 14.—Cold work.

Pressure to edge $\frac{1}{4}$ and $\frac{5}{16}$ inch thick 70,000 pounds steel, 2,500 to 5,800 pounds per running inch.

Whatever variation exists in doing the actual flanging is no doubt due to the variation in the steel, as the material upon which the experiments were made was allowed some latitude both physically and chemically. As to the variation in edging, however, this is mainly due to the difference in radius of curves and general shape of work.

When flanging hot materials it is difficult, if not impossible, to determine the exact pressure per running inch to do the work, because invariably a certain amount of

stretch accompanies the process. In fact, in many instances the necessity for doing so determines, in spite of any thickness, the question as to whether the material shall be treated hot or cold. With hot work, wrinkling or waving is also a strong factor which has to be considered. A number of experiments were made on some $\frac{1}{4}$-, $\frac{7}{16}$- and $\frac{1}{2}$-inch plates, all heated to a bright red, and the resulting figures were as follows:

Pressure necessary to bend the plate and commence the actual flanging varies from 185 pounds per running inch for $\frac{1}{4}$-inch material up to 380 pounds for $\frac{1}{2}$-inch.

Pressure necessary to complete the flange and sharpen corners varies from 2,100 pounds per running inch for $\frac{1}{4}$-inch material up to 2,700 pounds for the larger thicknesses, depending greatly, as a matter of course, upon the temperature of the plate.

Pressure necessary to remove waves or wrinkles on a flanged surface = about 1,400 pounds per square inch of waved surface. The latter represents such cases where the wrinkles are not of exceptionally heavy amplitude.

The middle figures, namely, 2,100 to 2,700, contain also the power necessary to overcome a certain amount of stretch incident to the process.

The energy consumed in flanging $\frac{1}{4}$- and $\frac{3}{8}$-inch hot steel plates was found as follows:

For $\frac{1}{4}$-inch material, 100 foot-pounds per running inch or 400 foot-pounds per square inch.

For $\frac{3}{8}$-inch plates, 360 foot-pounds per running inch or 965 foot-pounds per square inch.

Summing up the general features of the third system, we find the resistances to flow as being very gradual in their increase—commencing at zero—and following a line of increments which, toward the final end of its stroke, rises more or less rapidly, depending upon the amount of movable surfaces enclosing the materials to be treated. The metal flows exclusively in the line of pressure, only changing its direction when the motion becomes impeded by meeting a stationary surface, more or less perpendicular to the line of flow.

This constitutes about the limit to the field upon which the speaker has experimented. There are unquestionably some other directions into which the flow of metal enters and which are of importance to the engineer; as, for instance, the reduction of metal when compressed between a pair of revolving rolls; but, I think, nevertheless, that the different processes mentioned in this paper will cover most of the branches of the mechanic arts in which the designing engineer is interested when pursuing his profession.

A number of years ago when, in the line of my duties, it came that I had to design some shearing machinery, I naturally looked around for figures regarding the power necessary to sever metals; and this was my first effort in examining existing published results. My examination covered the publications of different nations as well as of different authors. It was, however, all in vain. What little data the scientific literature did reveal was of a crude character, and did not possess accuracy or logical reasons for its deductions. I then commenced to experiment myself; and little by little my field was increased, until it covered all the topics which I have given you this evening. An entire night could undoubtedly and advantageously be given to each subject, but I thought when covering the field as a whole, it would be easier to see and appreciate the similarities or the differences existing between each particular flow and a better understanding reached than if the subject were split up into details.

If the information given above proves of any advantage to the engineering profession at large, I shall more than consider myself repaid for all the work and trouble involved in carrying out the investigations; and I believe, gentlemen, that the truest and best engineer is after all the one who will combine sufficient ethics with his profession, so as to make him feel that, independent of his obligations to himself and his immediate surroundings, he also owes a debt to the science which has stood by him and enabled him to secure a reputation and livelihood.

Discussion.

Mr. James Christie:—It has hitherto been the usual practice to consider that the resistance to punching per unit of section cut exceeded that of ordinary shearing. This seems reasonable when we consider that the tendency to flow in either case is less restricted in shearing than in punching; in the latter case the act of detrusion is resisted by the clinging of the surrounding mass of metal. Furthermore, the breaking moment which Mr. Loss describes as occurring in the act of shearing, and which operates through a leverage equal to the distance between centers of upper and lower knife, would facilitate the process of shearing; and it does not occur in the same sense in punching. It is, therefore, a matter of surprise when Mr. Loss informs us that his experiments indicate a lower maximum intensity of pressure required per unit of section for punching than for shearing. As the experiments have been numerous, and evidently conducted with care and forethought, we cannot challenge their accuracy without presenting some experimental data in contradiction. This the writer is unable to offer at present. It is to be hoped that Mr. Loss will continue, and will publish further work on the lines embodied in his paper.

Mr. Wilfred Lewis:—This paper treats of a subject of great interest, upon which comparatively little information can be found in print, and the Mechanical and Engineering Section of the Institute is, I think, to be congratulated upon the outcome of this, its first venture, in printing advance copies of its proceedings. The object, of course, is to bring out well-considered discussion, and as Mr. Loss suggests, it should be a pleasure for engineers to repay their indebtedness to the profession which sustains them, not by hoarding the information they have gained by hard study and experience, but by imparting it freely to others. In other words, let there be a liberal interchange of engineering data for the greatest good of the greatest number. Mr. Loss has given us a very comprehensive paper on the Pressing of Steel, and he has covered at one time three divisions of his work on the flow of metals, each

of which might well be made the subject of a separate paper. It is, therefore, to be hoped that we shall hear further from him and that the present paper will be followed by others setting forth more in detail the work upon which he has been engaged.

In my own experience, there have been several occasions when the information contained in this paper would have supplied the data for which a search was made in vain, and as a result William Sellers & Co. were obliged to do as Mr. Loss has done—make their own experiments and deduce their own conclusions. As a representative of this company, I therefore take pleasure in laying before the Section a few notes which I have gathered bearing upon the flow of metals. If they do not accord in every way with the experiments recorded by Mr. Loss, it will be interesting to point out the discrepancies, and their explanation may afford some further light upon the subject.

It is no doubt true that shearing is seldom, if ever, experienced without more or less bending combined, and as Mr. Loss suggests, the transverse stress due to bending may be the real cause of rupture in shearing. This depends somewhat upon the manner in which the work is held, and, in this connection, it is of interest to recall an experiment made about seventeen years ago on a piece of wrought iron $1\frac{1}{2}$ inches thick, as shown in *Fig. 1*. The bar was laid horizontally between the blades of a shearing machine, and, as the blades closed upon it, the bar was left free to assume a natural position during the process of shearing. When rupture occurred, the blades were imbedded upon a surface $\frac{7}{16}$ inch wide, and the bar had rotated through an angle of 20°. Assuming that the pressure over the imbedded surfaces was pretty evenly distributed as the result of flow in the metal, and that the top rake on the shear blades was about at the angle of friction, the bending stress can be shown in this case to have been about equal in intensity to the shearing stress. The principal stresses due to these bending and shearing stresses will be one of tension of about $\frac{5}{3}$ the intensity of shearing and one in compression of $\frac{2}{3}$ the shearing intensity. Therefore

rupture by cross-breaking should occur when the shearing stress reaches $\frac{3}{5}$ of the ultimate tensile strength. Although there may be some inaccuracies in the assumptions made, it will be seen that this observation upon the indentation of shear blades corroborates Mr. Loss' conclusion that shearing is really cross-breaking and that the intensity of shearing resistance is about $\frac{3}{5}$ the ultimate tensile strength. If the sheared section could be relieved of bending stress, its resistance would naturally be increased, and it is, therefore, surprising to find the resistance to punching given as

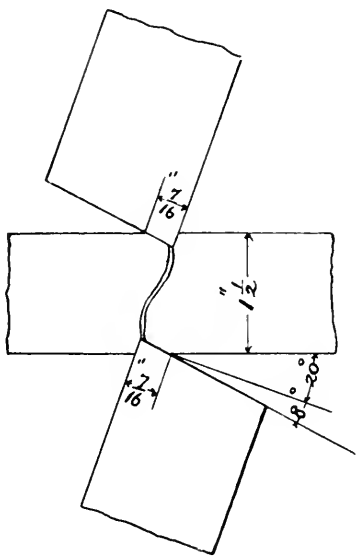


FIG. 1.

less than that of straight shearing. In punching, there is also some bending stress in the body of the metal punched out, but very little, if any, on the line of shear.

Possibly the figures given by Mr. Loss refer to bevelled punches, but if they refer to flat, they differ widely from the results obtained in my own experience.

The experiments bearing on this were made to determine the relative merits of flat and bevelled punches in material of different thicknesses. The punches were all $\frac{3}{4}$ inch diameter, with dies $\frac{1}{8}$ inch larger, and the material

ranged from ¼ inch to ¾ inch thick. One punch was flat, another V-shaped, the sides of which inclined 120°, and a third had an end in the form of a double spiral.

The punches and dies were set as usual in a punching machine, but the eccentric shaft was disconnected and the machine was turned on one side to bring the slide against the ram of a hydraulic wheel press. A pressure gauge on the cylinder indicated the working pressures per square inch from which the total pressures were estimated, and these divided by the surface cut through gave the following pressures per square inch in punching:

PUNCHING WROUGHT IRON.

			Hard Steel.	
Thickness of Metal.	Flat Punch.	Wedge Punch.	Flat Punch.	Wedge Punch.
Inch.				
¼	43,100	16,100	80,000	48,000
⅜	49,100	39,800	—	—
½	49,400	41,100	—	—
⅝	52,000	50,000	—	—
¾	48,500	52,100	—	—

STEEL BOILER PLATE.

Thickness of Metal.	Flat Punch.	Wedge Punch.
Inch.		
⅜	49,100	39,800
½.	49,400	49,400
⅝	52,000	58,200

The spiral punch did no better than the wedge punch and was soon damaged beyond further usefulness.

Care was taken to obtain a reliable gauge in making these tests, but, before accepting any disputed values, a repetition of the experiments in a different way, as, for example, between the heads of a testing machine, would seem desirable. It appears from these experiments, however,

that the shearing resistance in punching approximates very closely to the ultimate tensile strength of the material. On thin material the wedge punch naturally takes less pressure, but as the thickness approaches the diameter of the punch the value of the wedge lessens and finally disappears. On thin material also the flat punch requires less pressure per square inch of sheared surface, the cause of which may be looked for in the greater effect of the die clearance. When the metal is thin, the line of cleavage is more inclined than when it is thick, and a greater proportion of cross bending stress is thrown upon the sheared surface. It is therefore not surprising that, with $\frac{1}{8}$ inch clearance between punch and die, metal $\frac{1}{4}$ inch thick should require decidedly less pressure per square inch than metal $\frac{5}{8}$ inch or $\frac{3}{4}$ inch thick.

The question, therefore, remains whether punching pressures are really greater than those for straight shearing, and if so, why?

Another anomaly requiring some explanation is the energy per square inch consumed in cutting rectangular steel bars, given on page 468. It is perfectly clear that flat knives require more pressure in shearing than knives set at an angle to each other, but it is not at all apparent why the latter should consume less energy in shearing. Indeed, when it is considered that knives at an angle distort the piece cut off and have thus imposed upon them more work than that of shearing alone, it is reasonable to suppose that the energy consumed with angle blades should exceed that with parallel flat knives.

Again, on the same page the expression for the pressure required to shear angle iron makes this pressure depend upon the square root of the thickness of the metal, whereas, a little further down, the pressure required to shear flat bars is made to vary directly with the thickness. There is an apparent inconsistency in these expressions which makes it difficult to believe both.

The energy consumed in shearing is, I think, properly expressed in terms of the thickness squared, as given on the same page, and from this it can be argued that the shearing

pressure must vary directly as the thickness and not as the square root thereof. By analogy from shearing to punching, the energy consumed in punching should also vary with the thickness squared, and, as far as my experience goes, this is really the case, but I have no data on very deep punching where the metal removed is decidedly less in volume than the hole produced. But there are no examples of the latter kind of punching given in the paper, and yet on pages 471 and 472 the energy consumed is expressed in terms of the area of the hole without reference to the thickness punched through. It would therefore seem desirable to recast the values there given to accord in form with the expression given on page 468 for the energy consumed in shearing angles, where the thickness squared very properly appears.

In regard to riveting pressures it is shown pretty clearly in this example of cold riveting that excessive pressure will actually stretch the metal around the rivet and to a very marked extent when more than 300,000 pounds per square inch of rivet section is applied.

Our experiments on hot shearing and upsetting are too extensive to review in detail this evening. They were made upon a bloom shear at the Midvale Steel Works about fourteen years ago, and cards were taken by an indicator attached to a large steam cylinder, the plunger of which forced water into another large cylinder which did the work. Suffice it to say that as far as comparisons can be made our results agree very well with those given by Mr. Loss.

Physical and Astronomical Section.

INTRODUCTORY ADDRESS.

BY DR. A. E. KENNELLY,
President of the Section.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Friday, October 6th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The Physical and Astronomical Section of the Franklin Institute, brought to your notice this evening, is the youngest section which has been organized by that body, and, in fact, has not yet passed out of its first year of existence. We feel, however, no diffidence on this score, because the sciences which this section is intended to serve have already received the Institute's consideration under less specialized and divided guise. The mechanic arts themselves, for the cultivation of which the Franklin Institute was founded, are but working bees of the hive of Natural Science in general, and of Statics and Dynamics in particular. No man can design the simplest machine without some scientific knowledge, even though he does not know it by that title, and the more complex the machine, the more scientific knowledge he must possess.

Moreover, these sciences are themselves of the most remote human antiquity. Physics, in some form, however limited, must have been studied by man at every era of his existence, and we find that some practically-acquired knowledge of physical principles is even to be found in the lower animals. As for astronomy, or the natural philosophy of the heavenly bodies, it can only be second in antiquity to physics. The constellations look down upon us in much the same aspect that they looked down upon the earliest recorded times of our ancestors, and although they, too, reckon with time and change, yet by comparison with ourselves they stand out to our gaze as emblematic of immutability.

There are two peculiarities of the exact sciences, to the devotion of which this section has been created. One is that they manifest a tendency to speak in the exact language of mathematics, and the other is that difference of opinion tends to disappear upon the subjects which they adopt. Upon practically every subject which is not included in the exact sciences, except recorded history, there exists, as a rule, a great variety of opinions, and the difference of opinion generally increases with the distance of the subject from the sphere of exact science. On such questions as the Monroe Doctrine, or the comparative beauty of orchids and geraniums, or the probable future of the Chinese Empire, we may expect to find every variety of opinion and judgment. But upon the area of a circle of two feet radius, the shape of the earth, or the distance of the moon, there is practically no difference of opinion, and such difference of opinion as does exist is restricted to such narrow limits of uncertitude or precision as to the uninitiated seems trivial and incongruous. Yet we know from history that there have been times when men disputed vehemently upon all of these questions; that is to say, before the exact sciences were sufficiently powerful to annex them. We find, indeed, vexed questions and disputes in the domains of the exact sciences, but, as a general rule, these are only on matters which have thus far eluded complete measurement and systematic generalization. The law of these questions has not yet been discovered, and for this reason they are still outside the empire of exact science. As time goes on, labor achieves, and knowledge advances, these things become measured and known, whereby dispute terminates and dissension disappears. Whether we should care to live in a world where everything belonged to the exact sciences, and in which the cause and order of all things could be found in the encyclopedia, is, of course, open to debate; but it is beyond dispute that the practical unanimity of educated opinion, upon subjects included in the exact sciences, entitled those sciences to a dignity and importance that is withheld from communities of facts that obey, as yet, no recognized law.

On looking back through the history of past centuries, it is impossible to avoid recognizing the fact that the exact sciences of the remote past had but very little practical application. Astronomers, while devoting their lives unremittingly to the study of the heavenly bodies, and fully impressed with the dignity of their task, cast horoscopes and predicted nativities. Physicists, such as Archimedes, occasionally performed useful services for the community; but many mathematicians, such as Pythagoras, disdained all utilitarian aims as unworthy of their study. To them, knowledge, jealous of the attention of her devotees, frowned at all flirtations with utility.

The necessities of modern civilization, however, have swept away the prejudices that encompassed and secluded scientific research. We could not maintain the fabric of existing institutions without the aid of the applied sciences.

It is very doubtful whether the existing population of cities like London and New York could even be sustained in food, if the applied sciences were in the stage of their development at the beginning of this century, before the locomotive steam engine made its appearance. Even if the necessaries of life could be carried in to the cities from the surrounding country, in sufficient quantities, by horse wagons, the cost of transportation would make city life economically impossible to a large section of the community. Without the machinery which is the outcome of applied science, our clothing, shelter and food would require all the average man's time and effort to secure for his family and himself, and luxuries would become impossibilities. The federal government of such a large area as the United States would become a practical impossibility under the same circumstances. It is recorded that in 1812, before the days of the electric telegraph, the Government at Washington did not receive the news of the battle of New Orleans until more than three weeks after the event.

The absolute dependence of modern civilized society upon the work of the applied sciences is so great that these sciences are taxed to their utmost limit. More and better machinery is needed, cheaper, simpler and more effective than

existing machinery. Competition among machines is to-day keener than the competition among men, because even the most systematic men are subject to some erratic or variable impulses which reduce the closeness and keenness of their mutual competition; whereas, machines, while maintained in repair, work with a zeal that knows no weariness and a regularity that no emotions can disturb. The result is that all the engineering sciences and applied sciences generally are taxed to their utmost to supply the needs of society. These applied sciences turn eagerly to the exact sciences for fresh material to place at the public hand. In former years there was so little demand for the applied sciences that the pure sciences only gave their rejected surplus to applications. Now the demand is so great that a large amount of purely scientific work is done in the world each year, in the hope that some of the results can be made available for utilitarian purposes. The study of the steam engine for the purpose of cheapening and improving it has added enormously to the world's scientific knowledge concerning the laws of thermodynamics. The first endeavors to lay the Atlantic telegraph cable added in a great measure to scientific knowledge concerning the ocean and its doings. The study of guns for use in war has contributed largely to the stock of accurate information concerning the motion of projectiles in resisting media. Conversely, it is almost impossible to discover any new scientific fact without finding a useful purpose for it to fill. Röntgen, for example, had scarcely more than announced the discovery of his new invisible rays, when surgeons began to use them. After looking back upon the past, it is impossible to look forward without being convinced that the practical man of the future will be more of a scientist than ever. Current literature, current speech and current development all make this confession of faith. In the days that are now behind us, an inventor who had only acquired a very moderate amount of applied science, by untrained observation and experience, could, by native ingenuity, introduce great improvements in the relatively crude industrial processes of his time. In the days that are before us, however, industrial processes

are becoming so specialized, so complex and so linked with mechanical processes, that an inventor must be possessed of either greater natural ability to improve the result, or must have received some scientific training. In fact, whereas it was at one time true that "necessity was the mother of invention," it is now more nearly correct to say that science and necessity are the parents of invention. Natural science is in the last analysis, only the study of natural phenomena and of their laws, and the more complex the machinery by which those laws are controlled for industrial purposes, the more intimate must be our knowledge of them.

The benefits which have been derived during the past seventy-five years—the lifetime of the Franklin Institute—from the progress of the exact sciences and their industrial applications have been numerous. They have so modified nearly every industry as practically to revolutionize it. Where, perhaps, one hundred men then labored with weary arms, one or two men now accomplish the same result with the aid of machines. The result of all this has been that the total production of communities, per worker, has been enormously increased, so that although the average hours of labor have somewhat decreased, the average purchase of a day's labor in money has increased appreciably, and its purchase in commodities has increased very markedly. The application of the exact sciences to the forces of life has made and must continue to make life easier, brighter and more comfortable to the average member of the community.

The exact sciences pour more than pure wealth into the lap of the nation that applies them. They also ennoble. Ignorant man, the man of very limited science, is swathed in superstition; he sees a particular spirit in every natural phenomenon and a demon in every adverse circumstance. Gradually, as he learns the laws of his environment, his superstition melts away, more intimate appreciation of the nature of the universe raises him mentally and morally, while the greater control he obtains over the processes of nature, the higher the elevation to which he rises. The average man of the community to-day possesses much more

scientific knowledge than did the average man of past centuries. The average man of the community to-day is better, brighter and more comfortable, for his knowledge as well as for his power. Acquaintance with the laws of the universe, which cannot falsify, unconsciously teaches truth to all those who learn them, while the capability of being able to transport material from New York to Chicago in twenty-four hours, and the ability to converse over the same distance by telephone, is a partial apotheosis of the entire race in which the ability resides. Every new achievement of this kind which science brings within our grasp, elevates humanity to a higher and nobler plane, and every earnest worker necessarily contributes to the elevation of his race.

It is, then, to the applied sciences of the future that we must look for the advances that are to make the world happier and greater than it is to-day. The result must come if no cataclysm intervene; for the forces of civilization, once given headway, are self-supporting and inevitable in their tendency. The applied sciences in their turn look to the exact sciences for development and support. The fostering and development of scientific training, knowledge, skill and application, is of vast importance to the community at the present time. That country and race and language must predominate in the world by which the natural sciences are most abundantly applied. There are no public institutions, except the hospital for the care of the sick, and the school for the education of the young, which are of more importance to the community than institutions which, like the Franklin Institute, cultivate the knowledge and application of the natural sciences.

SOME NOTABLE CONTRIBUTIONS OF AMERICAN PHYSICISTS DURING THE LAST THREE-QUARTERS OF A CENTURY.

BY T. C. MENDENHALL,
Honorary member of the Institute, President of the Worcester Polytechnic Institute, Worcester, Mass.

[An address delivered in Convention Hall, National Export Exposition, Friday, October 6th, at the Commemorative Meeting of the Chemical Section, on the Occasion of the Seventy-fifth Anniversary Exercises of the Franklin Institute.]

The cheerfully optimistic spirit which, fortunately, prevails everywhere and always among the masses of the people, easily and naturally leads to the conclusion that the present age is the golden age. Of all times in the history of the world, NOW is the most important. Never so much wisdom as now; never so much wit and courage and beauty as now; never so many things that make life worth living as now. So it was one hundred and two hundred years ago and so it will be one hundred and two hundred years hence, for the delightful disposition to accept things as they are, and not only to accept but to approve and admire, is a large and important element in that wonderful resilience which enables the human race to smile at discouragement and defy disaster. Moreover, it is a logical acceptance of evolution; an unconscious recognition of a development from worse to better, on the whole, steady and persistent.

But when one makes even a superficial examination of the centuries that have preceded our own, notwithstanding the meager knowledge we possess of some of them, it is immediately evident that such a view of existing conditions has not always been sound. It is at once seen that the progress of the race has not always been steady; that it has sometimes and for considerable periods inclined towards the worse, rather than the better, and that certain centuries stand in marked contrast with others when measure is taken of the intellectual growth and material development by

which mankind has been most profoundly affected. It is this fact which gives one whose life has been wholly in the nineteenth century courage to declare that the cycle of years now coming to an end is enormously more significant in its determination of the relation of men to each other and to the universe in which they live, than any that have gone before. Indeed, it is but conservatism to declare that the nineteenth century, along certain lines of development, especially those relating to the physical condition of man, must be credited with achievements beyond those of all past time. Argument in support of this proposition has become almost commonplace, and a brief reference to a few of the more striking illustrations will be sufficient, as it may also be necessary, to create a just appreciation of some contributions to this splendid evolution which will presently be considered.

One of the most notable transformations wrought during the century is found in improved locomotion, including the transfer of goods. We do not know who invented the wheeled vehicle. It was probably in use in prehistoric times. Nor do we know who first tamed the beasts, thus substituting the muscular energy of animals for that of men. But we do know that from that remote period to the end of the first quarter of the nineteenth century, nothing essentially *new* in the way of locomotion on land was invented. The coach in which George Washington rode differed only in details of construction from that chariot into which Joseph stepped, "arrayed in vestures of fine linen," and its motive power was the same. We do not know who first spread a sail to catch the power of the wind for propelling a boat, but we do know that, previous to the nineteenth century, no ship was ever driven otherwise. It is doubtful if the speed of travelling on land and sea was materially greater in 1799 than a thousand years earlier, although improved roadways and larger vessels lessened the cost per ton mile of freight. How startling is the contrast of these methods of locomotion, the total result of thirty or forty centuries of effort, with the accomplishments of the last three-quarters of the nineteenth century. But far more

amazing is the revolution which has taken place within the same period, in the methods of conveying intelligence from point to point. The telegraph and telephone could hardly have been conceived by even the most imaginative of those whose day preceded ours, and their influence upon the social and material conditions of men is yet far from its maximum. One of the most pregnant discoveries of all time was the art of controlling fire. The use of flint and steel for its production, which comes to us from the remote past, was still general during the first quarter of the century and many people are now living who were accustomed in their youth to "borrow" fire from their neighbors, in the absence of any means of creating it. The artificial light of the early part of the century was produced by methods not essentially different from those in use for thousands of years, the first real advance being the improved draught of the Argand burner. The clothing worn by our revolutionary forefathers was generally woven on hand looms and the parts were stitched together by hand, the whole process of production not differing materially from that of the "coat of many colors." During the earlier years of the present century, the harvest was gathered just as it was in the days of Ruth, and the several processes by which grain was converted into bread had altered little in thousands of years.

All of these are matters with which everybody is concerned, for food, clothing, fire, light and the means of bringing supply and demand together may be said to constitute the minimum requirements of human existence. In all of them the marvellous work of the nineteenth century overshadows that of all that have gone before.

One of the most important and suggestive books of recent publication is entitled "The Wonderful Century," by Mr. Alfred Russell Wallace, the distinguished English naturalist, who shares with Darwin the honor of conceiving one of the two most notable generalizations of modern science. In this work Mr. Wallace attempts an estimate of the value of the achievements of the nineteenth century as compared with those of all the centuries that have preceded it. In his summary he includes great inventions

and discoveries in both pure or theoretical and applied science. In all he enumerates thirty-nine, of which twenty-four are to be credited to the present century and fifteen to all previous time. While in the specific selection of these epoch-making events there is much room for difference of opinion, there cannot fail to be a general agreement as to the net result. The nineteenth is truly the "wonderful century," and whatever the twentieth or the twenty-first or the twenty-second may bring forth, this verdict is not likely to be reversed.

In reviewing the achievements of this century it is found, further, that by far the largest part of this industrial and social revolution has been enacted during the past seventy-five years, that is, during the life of the Franklin Institute, the seventy-fifth anniversary of the founding of which is now being celebrated. That it may justly exhibit pride in its long and illustrious career no one will deny, for its activity during this memorable period has contributed in no small degree to the large share which our country has had in the making of modern civilization.

My own duty on this most interesting occasion, as assigned to me by the Committee of Arrangements, is the presentation of a sketch of the progress of the science of physics during the period covered by the life of the Institute. The difficulty of the task which I have undertaken will be appreciated when I remind you of the fact that it is to discoveries in physical science and their application in invention and construction, that we owe by far the larger share of what goes to make this period unique in history. Indeed, it would be a task utterly impossible in the time to which I must restrict myself if I were to attempt anything like a general treatment of the subject. Even a limitation to a review of the contributions of American physicists to the progress of the science during this period would still constitute a performance impossible under reasonable conditions. I am compelled, therefore, to confine myself to what will be the merest outline of the work of a comparatively small number of those eminent men, living and dead, who have conferred honor upon their country by their splendid

contributions to physical science. I ask your indulgence and sympathy in attempting what cannot fail to be an utterly inadequate survey of a large field, and I wish especially to emphasize the fact that I make no pretense of thoroughness or of even enumerating all of those who would be justly entitled to mention in any other than a hasty sketch.

Natural science in the nineteenth century may boast of two great generalizations, of the conception and proof of two great laws or fundamental principles, against which the past might put the establishment of the Copernican theory of the solar system and the discovery and proof of the law of universal gravitation. One of them has been proved by observation, the other by experiment. The latter is the principle of the Conservation of Energy, which has been found an unerring guide in physical research. With the early history of this principle a countryman of ours had much to do. To an American, yet not an American, Count Rumford, is generally given the credit of being the first to fully realize and to distinctly announce the true character of heat as a form of energy. Driven from his home in New England by the cruel and now believed to be absolutely unfounded suspicions of his neighbors, he left his country only to return as her enemy, and while we have for a century profited by his subsequent generosity, we cannot fairly put his brilliant career as a scientific man to the credit side of our account. Barring Rumford's share in the principle of the Conservation of Energy, which is everywhere admitted to be large, it cannot be claimed that American physicists contributed largely to its establishment, at least not directly.

But in that domain of physical science comprehended by the term Radiant Energy, the contributions of American scholars during the past seventy-five years have been of first rank. Among the earliest workers in this field, and in many respects the most eminent, was Dr. John William Draper, and it is an interesting fact that his first scientific papers were published in the *Journal of the Franklin Institute*. Although an Englishman by birth, Draper was a

loyal American from the time he took up his residence in this country at the age of 21 years. While an undergraduate in the Medical College of the University of Pennsylvania he began to display remarkable talent for original research, and his first paper "On the Nature of Capillary Attraction" was published in the *Journal* of the Institute in 1834. In 1835, before receiving his degree, he published in the same journal his first paper on light, being an account of experiments to determine whether or not it exhibited any magnetic properties. During his long life of three-score and ten years he was a most industrious investigator and voluminous writer, but his most important work in pure science had to do with light. In this he anticipated many of the results of later researches, although due credit has not always been given him. He was one of the first to examine the influence of light in producing chemical changes and was among the pioneers in the science and art of photography. The first photographic picture from life was made by him, the face of his sitter, who was his own sister, "being dusted with a white powder." On a bright day a picture was secured in five to seven minutes. He also made the first photograph of the moon. As early as 1834 he had attempted, but without success, to photograph the fixed lines of the solar spectrum, and in 1837 he began a notable series of researches on the nature of rays of light in the spectrum, and with the splendid discovery of spectrum analysis his name must always be associated. In the course of this investigation he anticipated several of the fundamental discoveries of Kirchhoff, made public by him in a celebrated memoir thirteen years later than that of Draper. His paper, "On the Production of Light by Heat," was printed in the *Philosophical Magazine* for May, 1847, and in it he declared that he had established, experimentally, the following important facts:

All solids and probably all liquids become incandescent at the same temperature.

The rays emitted by solids from common temperatures up to nearly 979° F. are invisible; at that temperature they are red, and the heat of the incandescing body being made

continuously to increase, other rays are added, increasing in refragibility as the temperature rises.

Whilst the addition of rays so much the more refragible as the temperature is higher is taking place, there is an augmentation in the intensity of those already existing.

The spectrum of an incandescent solid is continuous; it contains neither bright nor dark lines.

These proportions are almost identical with those published by Kirchhoff in 1860, and upon which the spectrum analysis is founded. Had Draper made no other contributions to physics, his memoir of 1847 would have entitled him to high rank. But, in addition, he was the first to discover that in the ultra violet part of the solar spectrum there are absorption bands similar to the Fraunhofer lines of the visible spectrum. He studied the chemical effects of the different portions of the spectrum, the distribution of heat in the diffraction spectrum, the action of light on the growth of plants, and made many other researches which cannot even be mentioned here. He suggested, as a standard of photometry for white light, a piece of platinum foil of given area and thickness, heated to incandescence by an electric current of specified strength, thus, in fact, anticipating the incandescent electric lamp of Edison, and in a general way many proposed photometric standards of later date. Dr. Draper's tremendous intellectual activity was displayed in many fields and he is perhaps more widely known as the author of historical and controversial works than as a physicist. His "History of the Intellectual Development of Europe" is quoted with that of Buckle, and his "History of the Conflict Between Religion and Science" has passed through more than a score of editions in English, has been translated into nearly every known tongue, and was honored by a place in the "Index Expurgatorius," along with Galileo, Copernicus and Kepler.

Almost contemporaneous with Draper was Lewis M. Rutherfurd, whose scientific researches were also mostly made in the city of New York. Mr. Rutherfurd devoted much time and energy to the development of celestial photography, besides making important contributions to our knowledge of the solar spectrum. He constructed a

spectroscope with six large bisulphide of carbon prisms, using many ingenious devices for overcoming the many difficulties which the making of an instrument of such dimensions involved. Among these was the now well-known arrangement for adjustment of the prism to the position of minimum deviation for rays of different refragibility. The application of the photographic camera to this instrument resulted in a magnificent map of the solar spectrum, especially of that part extending from F to H, which was for a long time unequalled. His experience in the production of this photograph led him to undertake the making of a diffraction grating, with which he believed he could obtain more satisfactory results. The gratings with which the memorable researches of Fraunhofer had been made were of fine wire, varying in diameter from about one-twenty-fifth to about two-thirds of a millimeter. The grating space distances between the center of the adjacent wires ranged from somewhat more than one-twentieth to seven-tenths of a millimeter. With instruments so crude as these, Fraunhofer had measured the wave length of a few of the most prominent spectrum lines with an accuracy which must command our highest admiration, but he had practically exhausted the possibilities of a wire grating. Nobert had devised a method of ruling fine lines upon glass, but his secret was carefully guarded. Although capable of ruling lines very close together, the inequality of spacing which they almost invariably exhibited greatly lessened their value for optical researches. As early as 1863 Rutherfurd attacked this problem and with such success that, as a result of his own efforts, supplemented as they have been by the later work of Rowland, American diffraction gratings have been, and are to-day, incomparably superior to those made elsewhere. In Rutherfurd's first ruling machine the movement of the plate upon which the lines were ruled was accomplished by a system of levers, but a screw was soon substituted for this, on the suggestion of Professor Rood. With the new machine gratings were ruled upon glass and also on spectrum metal, the most perfect examples being of the latter type. As many as 17,000

lines to the inch, the lines being nearly an inch and three-quarters in length, were ruled with a perfected machine and with a uniformity of spacing previously unheard of. Indeed, the diffraction spectrum was seen as it had never been seen before. Physicists were now enabled to make accurate measures of wave length with even faint sources of light, and were thus put in possession of a new instrument of research of great value.

In this connection, mention should be made of Mr. Chapman, Rutherfurd's skilful assistant, who contributed much to the final triumph by his mechanical ingenuity and patient industry. Rutherfurd was a member of the National Academy of Sciences and other scientific societies. He was extremely modest and apparently indifferent to public recognition, and as a result his excellent work has not received that notice, either at home or abroad, to which it is justly entitled.

No account of the contributions of American physicists to our knowledge of spectrum analysis would be complete without mention of important investigations made by Dr. Wolcott Gibbs, now President of the National Academy of Sciences. Although a chemist rather than a physicist, Dr. Gibbs's researches have often led him into the domain of pure physics and his work has always been of the first rank.

Ignoring chronological order, it will be most fitting to refer, at this point, to the admirable investigations in the field of optics by which Rowland has contributed to the renown of American science. The scientific importance of Rutherfurd's improved gratings, and the interesting results growing out of their use, encouraged others to attempt the construction of ruling engines which should be still more perfect, for even Rutherfurd's best plates revealed certain irregularities in the spacing of lines, seriously interfering with their highest usefulness. The interesting problem was to devise a process by which a screw could be cut more uniform in pitch than that of the lathe on which the cutting was done. Professor W. A. Rogers gave much time and ingenuity to the solution of this problem and had

devised a method for correcting the errors of the lathe screw, by moving the cutting tool in a determinate manner. The solution was not entirely satisfactory, however, and when Rowland attacked the problem of making a perfect screw, he practically ignored all attempts to correct or allow for the errors of the lathe guide. Briefly, his solution, which was wonderfully complete, amounts to saying that a screw must first be cut as perfect as possible on the best lathe attainable and then it must be freed from errors by grinding in a long, reversible nut by which all sensible inequalities may be eliminated. Having prepared a screw in this manner, Rowland mounted it in a dividing or ruling engine and began to rule diffraction gratings. Great care was taken to shield the plate and machine from temperature changes or accidental disturbances during the process of ruling, and it is but just to say that the results were far superior to anything that had been previously accomplished. Moreover, Rowland hit upon the happy idea of ruling on a concave reflecting surface, so that the use of lenses might be dispensed with. He has enlarged the dimensions of these gratings and improved their quality to an extent no one had thought possible, and he has devised special forms of apparatus by which they may be used in photographing spectra. He has himself completed a most extensive series of photographic maps of the whole solar spectrum, on a scale enormously greater than any attempted before he made this special field his own. His gratings and photographic methods in the hands of other observers have been the means of adding greatly to our knowledge, not only of the solar spectrum, but of the spectra of the elements, stellar spectra, etc., and it may justly be said that no more important contribution to spectrum analysis has been made anywhere during the past twenty-five years.

In the determination of one of the most important optical constants, the velocity of light, it is universally conceded that American physicists have reached the highest degree of precision. So swift is the speed of light that it was long thought to require no time in travelling from point to point. Galileo thought it must have a finite velocity and made

some experiments to determine if this were true, but without success. In 1676, Römer, a young Danish astronomer, announced to the French Academy of Science his discovery of the velocity of light, by observations of the eclipses of Jupiter's satellites, and this important fact was confirmed not long after by Bradley, the English astronomer, in the discovery of "aberration," which furnished a much more accurate value of the velocity constant than that given by the Dane. For a long time it was not thought possible to measure the velocity of light, exceeding as it does 180,000 miles per second of time, by any other than astronomical methods in which the space travelled over was sufficiently great to require a measurable period of time. In the early part of this century, however, it became very important to devise a means of measuring very small intervals of time with such accuracy as to make it possible to determine the velocity of light travelling over short distances, and the skill of the ablest physicists was challenged to accomplish this result. The difficulty of the problem will be understood when it is remembered that light will travel a mile in a little more than one-two-hundred-thousandth of a second, and if that distance could be used as the base, for the result to be true within 1 per cent. it would be necessary to measure time correctly to within one-twenty-millionth of a second. The importance of the problem grew out of the fact that the emission theory of light, as conceived by Newton, still, up to the middle of this century, had many adherents, and an *experimentum crucis* which would forever determine between that and the wave theory was greatly desired. This presented itself in the relative velocity of light in rare and dense media, in regard to which the two theories were diametrically opposed to each other. Everybody knows how Foucault, taking advantage of an ingenious application of a swiftly-revolving mirror used by Wheatstone, in an attempt to measure the velocity of electricity, completely settled the question by a beautiful experiment which he reported to the French Academy on May 6, 1850. Finding the velocity less in water than in air, the emission theory of light was compelled to yield its last foothold. But there

were many other problems of great interest to be solved by more accurate methods of measuring the velocity of light and many physicists attempted to improve upon Foucault's process. The most successful of all was Michelson, a graduate of the U. S. Naval Academy, who so modified Foucault's apparatus as to insure an accuracy about two hundred times as great. In conjunction with Newcomb, America's most distinguished astronomer, he made a series of experiments which are everywhere accepted as the most refined determinations of this important constant. Michelson has since devoted most of his energy and talent to optical research, in every department of which he has met with signal success. In his invention of the Interferometer he has furnished an instrument for delicate research in light transmission productive of many very important results. In 1892 he succeeded in making a very precise comparison of the wave-length of light with the international prototype meter at Paris, the unit of length for the civilized world, and he has successfully carried out other researches in light too numerous to mention here.

Very important contributions to our knowledge of the solar spectrum have been made by Langley, Secretary of the Smithsonian Institution. They were begun at the Allegheny Observatory, of which he was director, and have been continued, being, indeed, still in progress at the Astro-physical Observatory at Washington. Langley made an important modification of Siemens's electric resistance thermometer, adapting it to the most refined problems of radiant energy, and in his hands the Bolometer, as it is called, has thrown a flood of light upon hitherto unexplored regions of the solar spectrum. He has especially explored the infra-red region of the spectrum and has been able to detect radiation of wave-lengths enormously greater than any hitherto found. He has utilized the same device in an investigation of the temperature of the moon, and in the study of sources of light apparently unaccompanied by heat. One of his most interesting researches has revealed the fact that the character of sunlight is greatly modified by absorption in its passage through the earth's atmosphere, and that the color

of the sun, if it could be seen unaffected by this absorption, would be a greenish-blue.

The restrictions of the occasion will not permit of further details of these interesting investigations or of other important contributions to optics made by American physicists. It is impossible, however, to omit a brief mention of the indebtedness of American students of optics, and of scientific men throughout the world, to the exquisite skill in the production of optical apparatus possessed by two or three American artists. Pre-eminent in this field have been the Clarks, father and sons, now alas! dead, and Brashear, of Allegheny, still in the prime of a life which has been devoted to the mastery of mechanical difficulties in the way of producing optical surfaces of the very highest accuracy. The almost unique position which American physicists occupy to-day in the domain of optical research is largely due to the delicate touch and brain-directed handicraft of these men.

Equally important extensions of our knowledge of that form of radiant energy known as heat have taken place during the last three-quarters of the century, but the contributions of American physicists have not here been so notable. Much has been done, however, worthy of mention, if only time permitted, and some record must be made of work in this field not already included in the investigations of Draper, Langley and others. Rowland's determination of the mechanical equivalent of heat will always rank as a classic. Following the general plan of Joule's famous experiment he greatly improved the apparatus, giving especial attention to the change in the specific heat of water with varying temperature, and the thermometric part of the work was much more precise than that of Joule. The practical value of the result was great, and the theoretical even greater, because it has destroyed certain discrepancies previously existing among values of this constant obtained by widely differing methods.

If I had to do with applied physics, there would be much to say of the share of our countrymen in the wonderful development and improvement of heat-engines and of the

enormously increased utilization of the energy of fuel, but this phase of the question I must not touch.

In that department of physics of which but little was known a hundred years ago—electricity and magnetism—our philosophers have been among the first. At the close of the last century our most brilliant scholar and diplomat, Benjamin Franklin, was the world's most distinguished electrician. When this institution which bears his name was assuming form seventy-five years ago, one who was destined to be second only to him in renown as a student of electricity was just beginning a series of investigations which added great luster to American science. Of the work of Joseph Henry in electricity, most of which was done while he was still a very young man, at the Albany Academy, I may be permitted to quote what I have said in another place. His first important work was the development and perfecting of the electro-magnet. With this now commonplace but most important electrical device three names will always be associated. Shortly after the announcement of Oersted's brilliant discovery, which furnished the first connecting link between electricity and magnetism, Arago had announced the interesting fact that if rods of steel or iron were placed in a glass tube around which a wire was coiled so that the adjacent rings did not touch each other, they would become magnetic on the passage of a current of electricity through the wire. Thus Oersted's discovery, that an electrical current would *influence* a magnet, was supplemented by Arago's, that it would also *produce* a magnet. Three or four years later another notable step in advance was made by Sturgeon, in England, who produced for the first time what has since been known as an "electro-magnet." He bent a bar of soft iron into the shape of a horseshoe, thus bringing the poles into the same plane for greater convenience; and he dispensed with the glass tube used by Arago, by varnishing his iron core, thus insulating the coils of naked wire, which he wound in a spiral about it. But the most powerful electro-magnets made by Sturgeon's method were insignificant compared with what Henry was able to produce a few years later. Instead of varnishing

the iron core and using naked wire, he insulated the copper wire itself by covering it with silk, and this enabled him to coil the wire closely and to make two or more layers about the core. This had the effect of enormously increasing the strength of the magnets produced, and Henry at once recognized the importance of the discovery. But he carried the investigation much further, examining into the relation of the battery to the magnet, developing two forms of the latter, which he called "quantity" and "intensity" magnets, and by the aid of the latter succeeded in making visible and audible signals at the end of a long line, which had been declared to be impossible by Barlow.

He actually set up in the hall of the Albany Academy a line more than a mile in length, through which signals were transmitted without difficulty, and the principles involved were so well understood by Henry, that even then—in 1832—he confidently declared that transmission through any reasonable distance was possible. This system was the germ of all modern telegraphy. At about the same time its development in Europe began; but at first and for many years all European systems were based on the phenomenon discovered by Oersted—the deviation of a needle on the passage of an electric current through a conductor near and parallel to it. While Henry was exhibiting his perfectly conceived and well-executed scheme for electric transmission to visiting friends, Baron Schilling, a Russian Councillor of State, set up a model of his proposed electric telegraph before the Emperors Alexander and Nicholas, the first of the many "needle" systems which prevailed in Europe for many years, but which were finally driven out by the superior merits of the American system. Schilling's telegraph required thirty-six needles for its operation, besides a complicated device for an audible signal to attract the attention of the operator.

In connection with his study of magnets, Henry also devised what is now generally known as a "relay," which is an arrangement by means of which an electro-magnet operated by one current is made to close the circuit of another battery, thus enabling a feeble magnet, requiring only

a feeble current, to set into operation another at any point in the circuit. Thus he had evolved all the essentials of a complete telegraph system, lacking only mechanical details which engineering skill and ingenuity might easily have supplied.

Had Henry been less a lover of pure science, or had his commercial instinct been more highly developed, the Albany Academy mile of wire would have grown into the telegraph system of America, instead of furnishing, as it unquestionably did ten years later, the principle upon which that system was founded. It has required a good many years to dispel certain illusions concerning the electric telegraph to which Americans were inclined to cling, but it is now tolerably well known among intelligent people that the first commercially successful electric telegraph line was *not* erected in this country; that the telegraph can in no sense be called an American invention, although the American system has proved to be so superior that it has long ago practically superseded all others; and that by far the larger share of the credit for the success of this system is due to Joseph Henry for his discovery of the scientific principles upon which that success depended.

In the meantime Henry was engaged in further researches of the very highest importance. He sought to use the powerful magnets which he was now able to construct in the solution of a problem which had thus far baffled the efforts of the ablest electricians in Europe. Having succeeded beyond all others in *producing* magnetism by *using electricity*, he hoped to be able to successfully attack the inverse problem, the *production of electricity from magnetism*. All physicists believed that this must be possible, but no one had hit upon the method of doing it. Curiously enough, another great experimental philosopher, also a young man, had set for himself the same problem and worked persistently upon it during the month of August, 1831. During the same month Henry began a carefully planned series of experiments, which unfortunately, owing to his duties in the Academy, he was obliged to give up, not being able to return to them for nearly a year. Entirely ignorant of Henry's

plans, Faraday, on the 30th of August, 1831—a memorable day in the history of electricity—made the capital discovery of *induction*, on which practically all modern electrical development is based. Entirely ignorant of what Faraday had done, Henry again took up the subject and had the good fortune to discover the identical phenomenon in another aspect, in which it is known as *self-induction*. In the more recent advances in applied electricity, self-induction has come to be a matter of primary importance, and time has served only to magnify the value of Henry's discovery. Learning of Faraday's experiments, he was led, through their verification, to discover induction by induced currents, concerning which he made a most interesting and valuable investigation. Of his many other important discoveries in electricity there is one that must not be passed without mention. It was that the discharge of a Leyden jar was oscillatory in character, in which he anticipated Helmholtz and Lord Kelvin in the recognition of a phenomenon which has, within a very few years, come to have a deep import. The present estimate of the value of Henry's work in electricity is reflected in the following remarks, made not long ago by one of England's leading electricians: "At the head of this long line of illustrious investigators stand the names of Faraday and Henry. On the foundation-stones of truth laid down by them, all subsequent builders have been content to rest * * * * In them (the scientific writings of Henry) we have not only the lucid explanations of the discoverer, but the suggestions and ideas of a most profound and inventive mind, and which indicate that Henry had early touched levels of discovery only just recently becoming fully worked."

In the study of Terrestrial Magnetism, the great work of Bache, begun in Philadelphia and continued with important extension in the United States Coast and Geodetic Survey, of which he was the most famous superintendent, is worthy of the highest praise. The work of Rowland in electricity and magnetism has been of much importance, and especial mention must be made of his beautiful experiment in 1876, in which he showed that a magnetic needle was affected by

a rotary disk carrying an electric charge, and also of his redetermination of the value of the ohm at a later date.

It is again difficult to resist the temptation to discuss the practical applications of electrical discoveries, for in this field it may justly be said that our countrymen have outranked all others. It would be a pleasure to relate something of the labors and successes of Wallace, the pioneer in the production of strong currents by the use of a dynamo; of Brush, who first solved the problem of arc lighting; of Edison, whose ingenious inventions in duplex and multiplex telegraphy have been eclipsed by his creation of the incandescent system of electric lighting; of Bell, whose beautifully simple device for the electric transmission of human speech startled the world in 1876, and has since all but revolutionized the conduct of the ordinary affairs of life; and of others who have contributed during the last quarter of a century to put the United States far in advance of all other countries in the application of scientific discovery to the improvement of the condition of mankind.

In other departments of physics American scholars have also had their share. In sound, important researches were made by Henry, and beautiful experimental investigations were carried out by Mayer, leading to important results. In meteorology, which is physics applied to the atmosphere, the names of Espy, Loomis, Ferrel and Abbe are everywhere known. The work of the Coast Survey in Terrestrial Physics, including magnetism and gravity, is universally admitted to be of the first order. In the application of physics to astronomy, American scholars easily rank with the highest; but into these and other regions I must not go, however much drawn towards them, for, unsatisfactory as my sketch is to its author, it must be brought to an end. It has been confined entirely to work accomplished and it has not ventured to suggest what the new century has in store. Within the last ten years a new group, almost a new school of American physicists, has made its appearance. With the enthusiasm and vigor of youth, prepared by the best of training under the most favorable circumstances, great in numbers and strong in purpose, these twentieth

century philosophers may be trusted to maintain the rank won by their illustrious predecessors and to add to their country's renown by the splendor of their achievements.

But it may be well to remind them that the problems which the nineteenth century passes on to the twentieth are not all related to science, pure or applied. How to use is often as important as how to produce. In spite of the enormous increase in the production of the necessities of life and the extraordinary diminution in their cost, their acquisition by the great majority of the race still means the exhaustion of their entire stock of energy. And this condition of things is being still further intensified by a steadily increasing proportion of idle, non-productive population, an element of both weakness and danger which modern civilization has thus far been unable to throw off. For the avowed purpose of keeping the peace, the world becomes a vast military camp, and it is not easy to decide whether scientific discovery has contributed most to the prolongation and betterment of human life or to the construction of improved machinery for its destruction. The cost of a single steel-clad battleship would establish, equip and richly endow a university, and the expenditure necessary to keep it in commission would maintain an institution for original research of such capacity and proportions that its output would be a never-ending blessing to all the people. Let us hope that among the glories of the twentieth century may be the recognition of the incongruity of a beneficence which seems to be founded upon the sentiment "Whom we would help let us first kill."

ELECTRICAL SECTION.

Stated Meeting held March 21, 1899.

A PHOTOMETRIC COMPARISON OF ILLUMINATING GLOBES.

BY ROBERT B. WILLIAMSON AND J. HENRY KLINCK.

Sources of artificial illumination do not, as a rule, radiate light in the direction desired. It is, therefore, necessary to control the direction of radiation by the use of "distributing" globes.

Further, the radiating surface has, usually, so great an intrinsic brightness as to give an unpleasant, glaring effect. This must be corrected by the use of "diffusing" globes.

The ideal globe should have both distributive and diffusive action, the extent and character of each being determined by the nature of the source and the kind of illumination desired.

The action of a globe in modifying the intensity of the light in a given direction is in general fourfold: First, the radiations striking the inside of the globe in the given direction are partly absorbed, leaving the emergent rays lessened in intensity; second, radiations originally not in the given direction are brought into that direction by reflection; third, radiations are brought into the given direction by refraction; and fourth, a portion of the radiations absorbed by the globe are emitted again by it, and thus becomes more or less luminous over its entire surface.

The tests described in this paper were made with the object of determining the relative merits of the various globes at present available for use in connection with the Welsbach incandescent mantle. The results given do not include all the data obtained, but are those which have been selected as being of most interest.

As no satisfactory "glare" test is known at present, the investigation was confined to the effect of the distributing

properties of the globes when used in connection with the Welsbach burner.

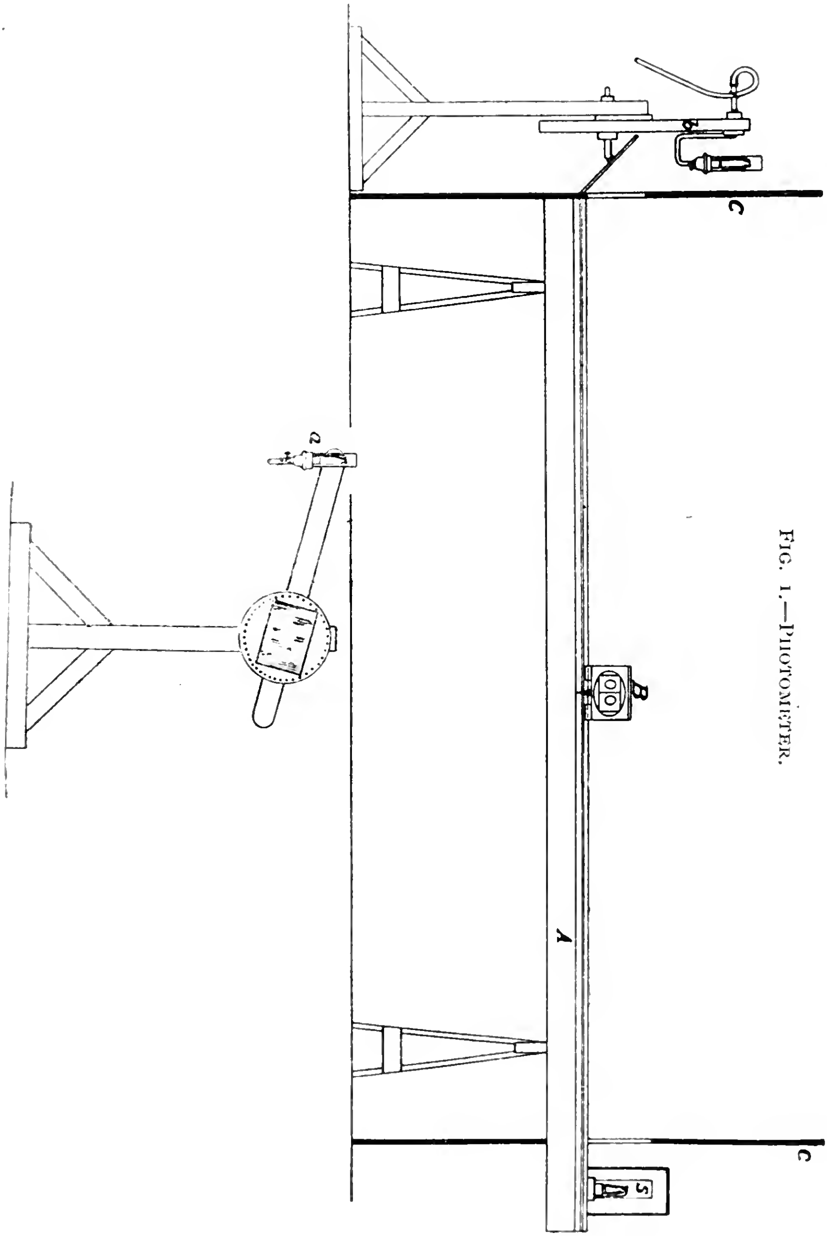


FIG. 1.—PHOTOMETER.

The tests were made by means of the Bunsen photometer. *A, Fig. 1*, is the bar upon which the carriage, *B*, containing the disc slides. *C* and *C* are two screens with openings in them opposite the sources of light, *s* is the standard, and *a* the burner upon which the globe to be tested is mounted.

The standard consists of a Welsbach burner, in front of which is a screen with a horizontal slit of such width as to cut off the extreme top and bottom of the mantle. These portions being subject to variations in brightness, due to the unavoidable dancing of the gas flame. The slit proved itself to be entirely satisfactory.

The burner, *a*, is mounted upon an arm, *b*, which rotates in a vertical plane about a pin in a fixed support. This pin is in line with the center of the disc in the carriage, and the center of the standard burner. Fastened to the arm, *b*, is an index plate, *c*, with holes 10° apart, a hole of the same size being drilled through the fixed support. By passing a tapered pin through this hole and the proper hole in the index plate, the test burner can be placed in any desired position with respect to the horizontal.

The mirror, *m*, is rigidly connected to the arm, *b*, and its plane makes an angle of 45° with the arm, *b*, the center of the mirror being directly in the line joining the center of the standard burner, the center of the Bunsen disc, and the pin about which the arm, *b*, rotates.

The burner, *a*, is so mounted as to be free to turn in a plane parallel to that in which the arm, *b*, rotates, its distance from the center remaining practically constant.

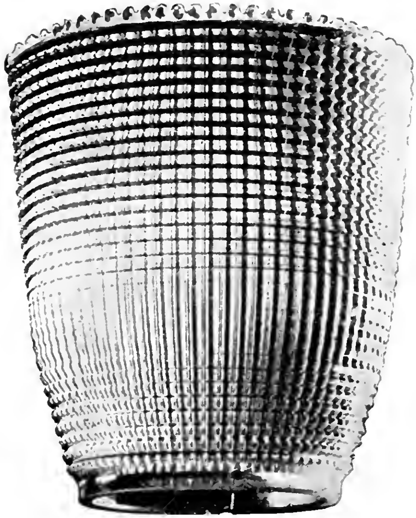
Rotating the arm, *b*, about its bearing, keeping the test burner always vertical, by means of a level, and taking readings for each position of the bar, *b*, the vertical distribution of light about the globes is obtained.

It is not possible to move the arm, *b*, entirely through 180°, for when at 90° below the horizontal the mirror is directly above the burner and is liable to crack. This necessitates the exclusion of the reading corresponding to a position directly over the lamp. This reading is certainly not greatly different from the one just preceding it.

Before obtaining the data, the mantles on the standard burner and the test burner were allowed to burn for some time to allow them to settle to a constant state; this was especially necessary whenever new mantles were used.

The distribution around the bare mantle was then obtained by taking two complete sets of observations, and checking them by a third set of partial readings.

The globe under test was then placed upon the burner, *a*, and two sets of readings taken, these being also checked by a third partial set. The bare distribution was then checked



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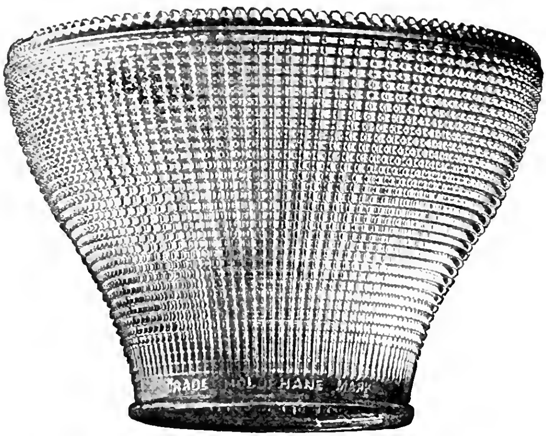
again, and in case of a disagreement between the final readings and the first ones, the test was repeated.

The mantles remained quite constant, the greatest trouble experienced being with the test mantle, due to the rough usage to which it was subjected. A small opening in the mantle would widen and change the distribution so much between the taking of the bare curve and the final check, that the mantles had to be discarded upon the first sign of breakdown. When one of the mantles gave out, both were renewed. It was found that the mantle is particularly sensitive to changes in the condition of the air; when the

room was at all close it was found impossible to obtain satisfactory results. Too much ventilation, on the other hand, caused a very annoying dancing of the flame, which, when present to a small degree, was satisfactorily annulled by the slit mentioned above.

The walls of the room, the screens and bar were all dull black, as were certain spots on the floor upon which the light fell, as at the beginning trouble was experienced when reading at angles below the horizontal, owing to reflected light striking the mirror and being thrown along the bar.

The Welsbach was used as a standard for the reason that



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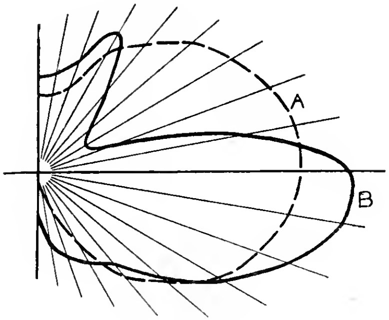
the Bunsen disc gives the most satisfactory results when the sources compared are identical in color. The ordinary mica chimney, commonly seen on Welsbach burners, was used throughout the entire series of tests.

Two observers were employed, one to read the photometer, the other to adjust the test burner and record the readings of the bar, as well as the position of the arm, *b*.

The globes, or reflectors, and the curves obtained from them have been given the same number in the figures to allow of easy reference from one to the other. In curve 7 is shown the distribution given by the flat, crimped, opal

No. 5.—Holophane. 1 inch = 20 c. p.



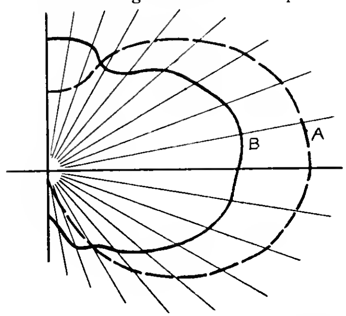
Bare lamp A.

Area above horizontal, 12·58.
" below " 11·15.
Total, 23·73.

Holophane B.

Area above horizontal, 7·92
" below " 12·72.
Total, 20·64.
Efficiency, 87 per cent.
Mean spherical, c. p., A, 46·46.
" " " B, 41·28.

No. 10.—Ground globe, egg shape, with wide flutings. 1 inch = 20 c. p.



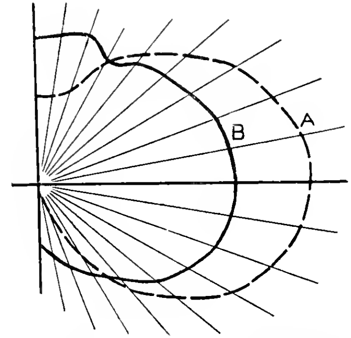
Bare lamp A.

Area above horizontal, 12·40.
" below " 10·78.
Total, 23·18.

Ground globe B.

Area above horizontal, 9·96.
" below " 8·44.
Total, 18·40.
Efficiency, 79·3.
Mean spherical, c. p., A, 46·36.
" " " B, 36·80.

No. 13.—Plain ground globe.



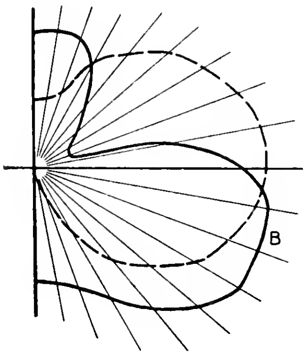
Bare lamp A.

Area above horizontal, 12·07.
" below " 11·4.
Total, 24·1.

Ground globe B.

Area above horizontal, 9·95.
" below " 9·95.
Total, 1·95.
Efficiency, 80·9.
Mean spherical, c. p., A, 48·2.
" " " B, 39.

No. 7.—Opal reflector. 1 inch = 20 c. p.



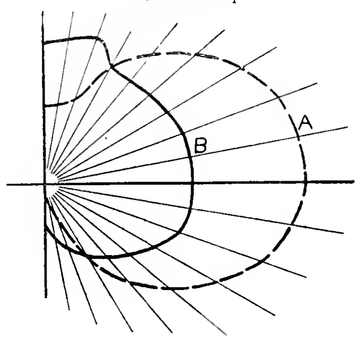
Bare lamp A.

Area above horizontal, 6·41.
" below " 14·20.
Total, 20·61.
Efficiency, 86·8 per cent.
Mean spherical, c. p., A, 46·46.
" " " B, 41·22.

Opal reflector B.

Area above horizontal, 12·58.
" below " 11·15.
Total, 23·75.

No. 11.—Plain opal globe (egg shape). 1 inch = 20 c. p.



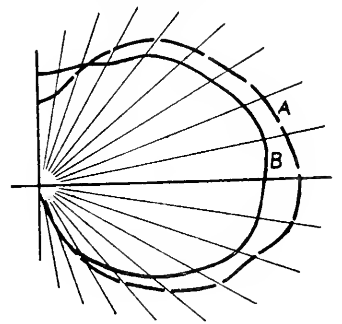
Bare lamp A.

Area above horizontal, 12·40.
" below " 10·78.
Total, 23·18.

Opal globe B.

Area above horizontal, 8·68.
" below " 7·21.
Total, 15·89.
Efficiency, 68·5 per cent.
Mean spherical, c. p., A, 46·36.
" " " B, 31·78.

No. 16.—Egg shape globe (light opalescent). 1 inch = 20 c. p.



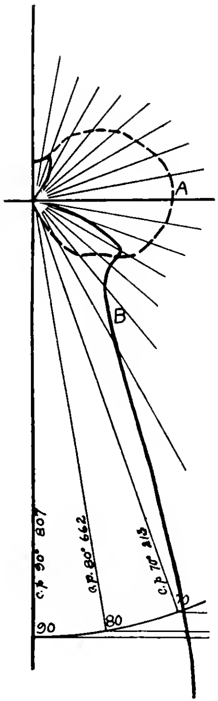
Bare lamp A.

Area above horizontal, 11·00.
" below " 9·60.
Total, 20·60.

Globe B.

Area above horizontal, 10·12.
" below " 8·48.
Total, 18·60.
Efficiency, 90·2 per cent.
Mean spherical, c. p., A, 41·20.
" " " B, 37·20.

No. 15.—Conical mirror reflector.



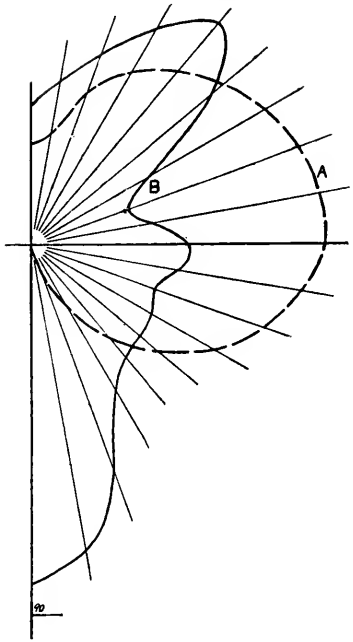
Bare lamp A.

Area above horizontal, 6·20.
" below " 5·52.
Total, 11·72.

Lamp, with reflector B.

Area above horizontal, ·62.
" below " 8·14.
Total, 8·76.
Efficiency, 74·7 per cent.
Mean spherical, c. p., A, 46·88.
" " " B, 35·04.

No. 19.—Holophane.



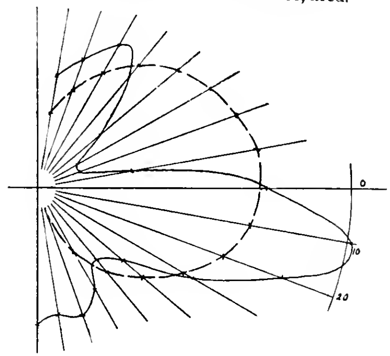
Bare lamp A.

Area above horizontal, 16·66.
" below " 12·38.
Total, 29·04.

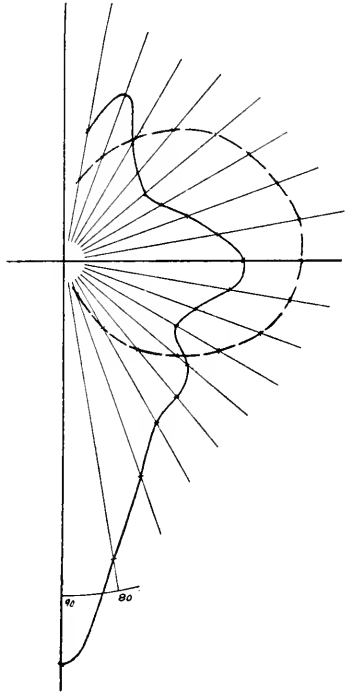
Holophane B.

Area above horizontal, 11·9.
" below " 10·52.
Total, 22·42.
Efficiency, 77·3.
Mean spherical, c. p., A, 58·08.
" " " B, 44·84.

No. 24.—Holophane, wide tulip, made from same tool as No. 20 surface, fired.

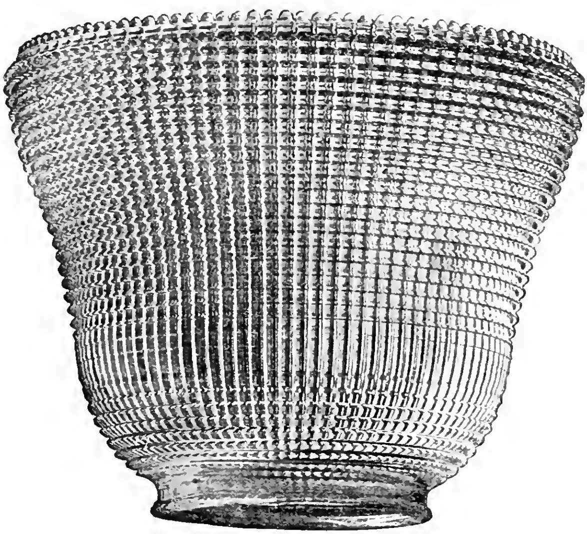


No. 27.—Holophane, pear-shaped holophane for vertical distribution.



reflector commonly used with the Welsbach mantle. (In the illustration the reflector is shown mounted upon a beaker.) The bare curve is shown by the *broken line, A*, and the distribution with reflector by the *full line, B;* this convention is used in all the curves.

From curve 7 it can be seen at once that not only is the light directly under the burner enormously increased, but that an increase occurs at almost every point below the horizontal. The large loop at the top in this, and the other curves, is due, in part, to the light which escapes through



24

the necessary opening in the top of the reflector, or globe, and in part to the light diffused by the globe. In the use of this reflector there is but one disadvantage apparent, that is, the glare of the mantle itself is not in any way reduced; this can be done with this reflector to a degree by the use of the small ground glass cup which is sometimes placed at the base of the chimney.

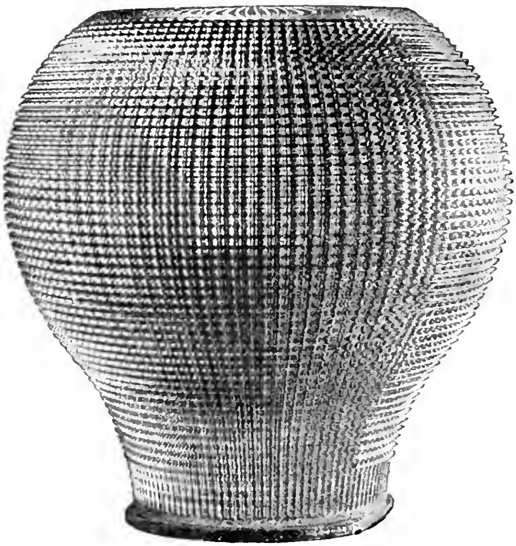
Globes 8, 9, 10, 11 and 16 all have the shape shown in illustration 16.

Curve 10 is from an egg-shaped globe of ground glass, the

fluting being inside and out, and being three times as wide as in globe 8. This curve shows an increase directly above and below the burner which would be noticeable under ordinary conditions. The absorption between 60° above and 60° below the horizontal is quite marked.

Curve 11 is from an egg-shaped globe of plain opal and is noticeable only for the large amount of absorption shown, the diffusion being, of course, the redeeming feature of this globe.

Curve 16 is from an egg-shaped globe of fluted opalescent glass, the fluting being both vertically and spirally.

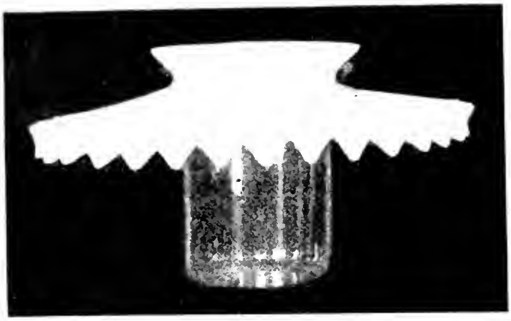


27

Globes 12, 13 and 17 are all of the shape shown in illustration 17.

Curve 13 is from a spherical globe of ground glass and shows its diffusive action by increasing noticeably the amount of light directly above and below the burner.

Curve 17 is from a spherical globe, the upper portion of which is ground, the lower being clear. The curve shows diffusive action upwards, although apparently designed to reflect the light downwards.



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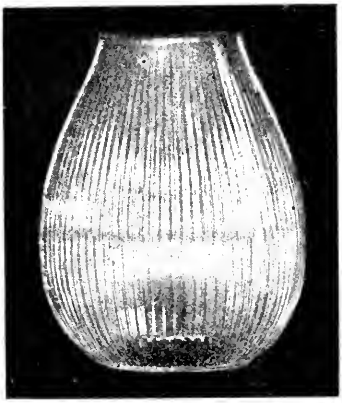

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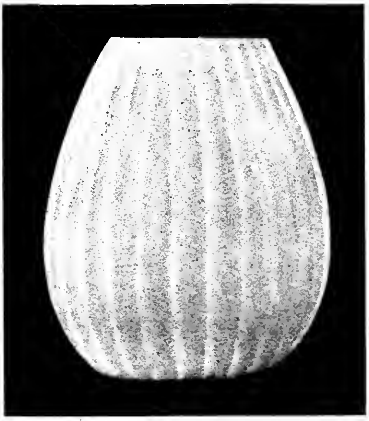

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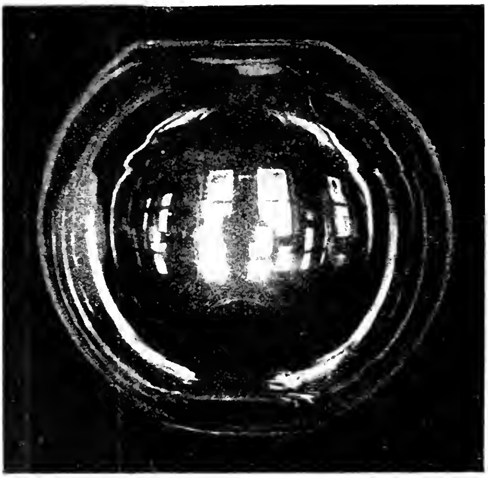

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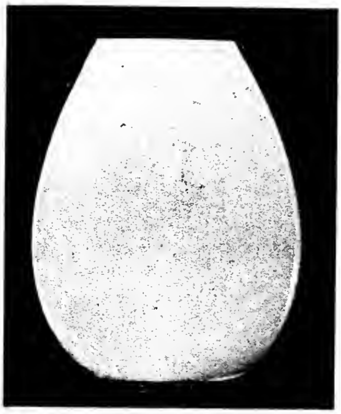

11

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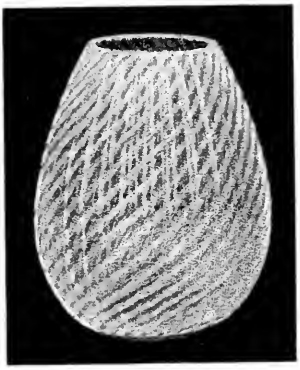
14

15



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17

Curves 14 and 15 are from mirror reflectors, shown in illustration 15. They are constructed of a number of segmental pieces of mirror glass held in position by means of a metal backing. Curve 14 is from a nearly flat mirror reflector. The light is thrown down and concentrated between 20° and 70° below the horizontal, the amount directly under the burner being very small.

Curve 15 is from the reflector shown (supported on a beaker) in illustration 15, the mirrors in this case making an angle of 45° with the horizontal. As a means of obtaining a brilliant illumination in a small space, this reflector gives the best results of any of those upon which data were obtained.

Curves 5, 19, 24 and 27 were obtained from "Holophane" globes. These globes consist of clear glass, with vertical ribs on the inside, and horizontal ribs on the outside. The inner ribs are all similar in shape, and the outline is that of a sine curve. The outer ribs vary in shape with the service for which the globe is designed, being simply prisms in the case of 19 and 27, and varying in outline in 5 and 24.

The general principle of construction being to refract or reflect the ray, from a region where it would be wasted to the point at which it is desired to use it.

Curve 5 is from a globe intended for nearly horizontal distribution.

Curve 19 is from a globe intended for street lighting, or general illumination, the major portion of the light being thrown below the horizontal.

Curve 27 is from a globe similar to 19, except for an added top portion. This curve has a higher maximum reading than 19. This, however, is not due to the top entirely, but to the fact that the globe had been "fire-polished," that is, heated enough to cause the surface to glaze over, and remove all traces of the mould. A globe similar in design to 19, but which has been fire-polished, gives a maximum reading very nearly equal to 27.

The selected results in this paper are offered as examples of the performance of the various types of globes available for use with the Welsbach mantle. They show that a

globe, or reflector, must be designed with due regard to the service expected of it.

No highly ornamental or decorated globes were tested, since these are used as a rule under conditions in which efficiency of illumination is not important, this being, in fact, of secondary consideration as compared with the artistic effect.

DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING,
THE LEHIGH UNIVERSITY, March, 1899.

NOTES AND COMMENTS.

COST OF GOOD ROADS AND LOSS FROM BAD ROADS.

In a paper read before the Engineers' Club of Philadelphia, recently, Gen. Roy Stone, Director of the Office of Road Inquiry in the United States Department of Agriculture, discussed "Various Phases of the Road Question," says *Municipal Engineering*. From data obtained from over 10,000 letters of inquiry, General Stone deduced certain figures, referring to the average length of haul from the farms to market or shipping points, the average weight of load hauled and the average cost per ton for the whole length of the haul. The figures, tabulated, are as follows:

GROUP OF STATES.	Average Haul, Miles.	Average Weight, Pounds.	Average Cost Per 2,000 Pounds Per Mile.	Total Average Cost Per Ton for Whole Length of Haul.
Eastern	5·9	2,216	$0 32	$1 89
Northern	6·9	—	27	1 86
Middle	8·8	—	*31	*2 72
Cotton	12·6	1,397	25	3 05
Prairie	8·8	2,409	22	1 94
Pacific Coast and Mtn.	23·3	2,197	22	5 12
Whole United States	12·3	2,002	25	3 02

* Middle Southern States.

Assuming the correctness of the data, and using the census return of farm products and forest and mineral outputs, and estimating incidental traffic, General Stone arrives at a total of 313,349,227 tons as representing the total annual movement over country roads. At the average cost, $3.02 per ton, the grand annual cost of haulage on public roads amounts to $946,414,665. Not including the loss of perishable products for want of access to market when

prices are good, and the uselessness of cultivating certain products which depend upon the markets being always accessible, statistics of the cost of operating foreign highways, and the data obtained from the use of the few good roads existing in this country, would indicate that nearly two-thirds of the above cost is directly chargeable to bad roads. The enforced idleness of men and horses during a large part of the year is another item which should be charged largely to bad roads The negative or hostile attitude of the rural population toward all effective legislation in this direction is an obstacle also to road improvements in this country, while another is the general over-estimate of the cost of such improvement.

A few years ago the macadam roads of New Jersey cost $10,000 per mile; now equally good roads are being built for $3,000, even where railway transportation of material is required; and in localities better supplied with road material, and where a narrower road is deemed sufficient, $1,500, or even less, will make a mile of good stone road. Experience has demonstrated the fact that in most country districts a single stone road, 8 or 10 feet wide, with a good earth road on one or both sides, is more generally satisfactory than a wider road of macadam.

An interesting German invention provides for instantaneous soda water in siphons. The device is called "sodor." It consists of a siphon provided with a wicker covering. The top is of peculiar construction, and admits of the insertion of a pear-shaped, thin iron capsule, filled with liquid carbon dioxide gas. The top of the siphon is hinged, and after it is swung into place a lever is pushed down which forces a piercing pin through the "sodor" capsule. The gas then forces its way out through special channels into the top of the siphon and impregnates the water in the siphon. The thick walls of the bottle are not readily broken by the pressure of the gas. This device will undoubtedly prove of considerable interest to those who live at a distance from bottling establishments.

The question as to the best means of isolating a freezing mixture is one of considerable practical importance in chemical and physical work. In a recent number of the *Berichte*, Prof. W. Hempel describes a series of comparative experiments undertaken by him to settle which substance was most suitable for ordinary work. Starting with a temperature of about — 75° to — 80° C., produced by solid carbon dioxide and ether, the rate of rise of temperature with time was measured, and, as a result, eiderdown was found to be the best insulator, wool carefully dried at 100° C. being nearly as good, and having the advantage of cheapness. Three samples of vacuum tubes, of the pattern invented by Professor Dewar, were also tried, and were found to give very varying results amongst themselves, and all being much inferior in insulating power to either eiderdown or cotton wool. Thus with eiderdown a rise of 12° C. occurred in eighty-eight minutes, with dry wool a rise of 20° to 24° C. in the same time, whilst the three vacuum-jacketed tubes gave under the same conditions rises of 65°, 69° and 39° respectively. The results would seem to show that trustworthy Dewar tubes cannot be bought commercially.

A SURFACE-CONTACT SYSTEM FOR ELECTRIC STREET RAILWAYS.

At the last British Association meeting, Prof. Silvanus P. Thompson and Mr. Miles Walker presented a joint paper, describing a system of transmitting an electric current to a street car motor by means of metallic studs placed at intervals in the roadway, contact being made between the conductor—which is underground—and the motor on the car by means of a sliding shoe or skate of sufficient length so as to be in contact with two studs at once.

From the account of the system in the *English Mechanic*, the authors claimed that this system would obviate the use of the overhead wire used in the trolley system, and also the continuous slot in the roadway which is necessary with the underground conduit system. There could be no danger to pedestrians from electric shock in crossing the road and stepping on the studs, for these could only be energized and the current set up by contact with the skate under the motor car.

INDUSTRIAL COLOR PRINTING.

A machine has been introduced into England for printing in colors which, says *Engineering*, is in its operation a departure from any machine hitherto used for a like purpose. It is the invention of Ivan Orloff, chief engineer and manager of the Russian Government Printing Works, at St. Petersburg, and it possesses many points of interest. In the ordinary flat color printing machine the successive colors are applied one at a time as each one becomes dry, but the Orloff machine puts down all the colors on the paper at once, so that a great saving of time is effected.

The principle of the machine is as follows: The blocks which take the different colors are fixed to a cylinder of large diameter, and each block receives the supply of colored ink intended for it, and as the cylinder revolves the ink on each block is transferred to a composition roller very similar to an ordinary inking roller. After all the colors have been transferred to this roller, each in its proper position, an engraved block or form follows and receives a perfect impression from the composition roller.

Thus impressed, the form passes on and comes in contact with the paper on the impression cylinder, where it prints all the colors at one operation. The whole of these varied transfers are performed during one revolution of the cylinder. While the blocks pass under the inking rollers the latter are, at the proper time, lowered by a system of cams so as to come into contact with the blocks which they are intended to ink. The number of colors that can be used is only limited by the number of blocks and the size of the machine. All the operations go on continuously, as the cylinder revolves in one direction only. The number of finished impressions is stated to be about 1,000 an hour. The machine was originally designed for the Russian Government to print multi-colored patterns for bank notes, and it appears to be well adapted for this purpose.

Franklin Institute.

(*Proceedings of the Stated Meeting held Wednesday, December 20, 1899.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 20, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 113 members and visitors.

Additions to membership since last report, 45.

The following gifts were reported:

A portrait in oil of the late Isaac P. Morris, for many years prominently identified with the Institute, presented by John T. Morris; an American flag of spun glass, made and exhibited at the glass works on the esplanade of the National Export Exposition, from Messrs. Gillinder & Sons, Inc.; specimens of rose quartz, from the Bridgeport Wood Filler Company; specimens of aluminum and Dutch metal foil, from the Sayre Metal Company; a number of chilled cast-iron balls, from the Cayuta Wheel and Foundry Company; specimens of slate from the Slatington-Bangor Slate Syndicate; specimens of iron ore, dolomite and limestone, from the Virginia Coke, Coal and Iron Company; an ornamental slab, cut with a pneumatic tool, from the Chicago Pneumatic Tool Company; and samples of steel for tools and dies, from the Crescent Steel Company.

The Secretary was directed to make proper acknowledgment of the gifts, with the thanks of the Institute.

Acknowledgment of election as an honorary member of the Institute from Mr. Chas. Kirchhoff, of New York, was read by the Secretary.

The following nominations were made:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL,
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. O. GRIGGS.

For *Managers* (to serve three years).

ARTHUR BEARDSLEY,	H. W. JAYNE,
HENRY C. BROLASKY,	LAWRENCE T. PAUL,
JAMES CHRISTIE,	HORACE PETTIT,
F. LYNWOOD GARRISON,	OTTO C. WOLF.

For *Members of the Committee on Science and the Arts* (to serve three years).

HENRY F. COLVIN,	JOHN M. HARTMAN,	LOUIS E. LEVY,
THOS. P. CONARD,	CHAS. C. HEYL,	TINIUS OLSEN,
GEO. S. CULLEN,	H. R. HEYL,	LUCIEN E. PICOLET,
CHAS. DAY,	GEO. A. HOADLEY,	GEO. F. STRADLING,
ARTHUR FALKENAU,	HARRY F. KELLER,	W. F. WILLCOX.

The paper of the evening was then announced.

"The Tower Clock in the City Hall, Philadelphia," by Mr. Warren S. Johnson, of Milwaukee, Wis., the designer and constructor. The speaker in-

troduced the subject by a reference to a number of the most notable clocks erected for public service, and proceeded to the description of the details of the Philadelphia instrument, illustrating the subject with the aid of numerous lantern slides. (Referred for publication.)

The President expressed the thanks of the meeting to the speaker for his lucid description of an apparatus of much local importance.

Mr. Louis E. Levy described and exhibited in operation an improved form of his acid-blast apparatus for etching metal plates, first shown at the stated meeting of February, 1899. The more important improvements relate to provision for preventing the heating of the acid, thus enabling higher blast pressure to be used, and increasing the rapidity of the etching process, and in employing aluminum in the construction of the entire apparatus. The apparatus, as now built, affords an interesting example of the indifference of this metal to the continued action of dilute nitric acid.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, December 6, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted :

Pocket Recorder for Tests of Materials. Gus. C. Henning, New York.

This report, of which an abstract appears in the *Journal* for December, was amended in certain particulars, and the applicant was awarded the Edward Longstreth Medal of Merit.

Drawing Tables. Samuel J. Laughlin and James Hough, New York.

ABSTRACT.—The invention is secured by letters-patent of the United States to the applicants, No. 550,413. The apparatus consists essentially of a drawing-board across whose surface a straight-edge or ruler is arranged to move into positions always parallel to itself. With these essentials are combined devices for adjusting the drawing-board or the paper, to facilitate the plotting of angles or the measurement of lines in all kinds of instrumental drawing.

The special features of these instruments cannot be explained without the aid of diagrams.

The finding of the investigating committee is stated in the following terms: "In view of the originality displayed in devising a parallel-moving straight-edge and rotatable drawing-board, and the excellence of their operation, in combination with other time-saving devices as applied in the Laughlin-Hough drawing tables," the award of the John Scott Legacy Premium and Medal to the inventors. [*Sub-Committee.*—L. F. Rondinella, Chairman ; J. Logan Fitts.]

Street Railway System. Andrew McGill, Dunedin, New Zealand.

The inventor's proposition is to construct a conduit of sufficient capacity to receive the truck and running-gear of an electric or cable car, having a

slot at the street surface to communicate with the same. Attached to this truck, and passing through the slot, are thin, wide bars, of sufficient cross-section to support the body of the car above. Special provision is made to facilitate passage around curves.

The investigating body believes that the disadvantages of inaccessibility to the truck mechanism, especially in the case of electric railways, where prompt access to the motors and their connections is of the highest importance, would more than offset the advantages claimed for the invention. [*Sub-Committee.*—James Christie, Chairman; Francis Head.]

Apparatus for Generating Acetylene Gas. Eugène Bournonville and Joseph N. Goldbacher, New York City.

ABSTRACT.—This apparatus belongs to the class of drop machines, *i. e.*, in which the calcium carbide is automatically fed in small quantities into relatively large quantities of water, the dropping device being actuated by the downward motion of the bell of the gasometer connected with the apparatus.

The apparatus is covered by letters-patent of the United States granted to applicants.

Reference is made to these for details of construction, which could not be made intelligible without illustrations.

The report speaks approvingly of the merits of design and mechanical arrangement embodied in the machine. [*Sub-Committee.*—Charles A. Hexamer, Chairman; Harry F. Keller.]

The following reports passed first reading:

Nut-locking Washer. James Walsh, Jr., Philadelphia. [An advisory report.]

System of Ventilation. Geo. W. Yearicks, Philadelphia. [An advisory report.]

System of Oil-heating and Incandescent Lighting. Arthur Kitson, Philadelphia.

Method of Recording and Reproducing Sound. Thomas H. MacDonald, Bridgeport, Conn.

The last two reports were held over for final action until the next stated meeting.

W.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, held Tuesday, December 19, 1899. Vice-President Dr. W. J. Williams in the chair. Present, thirty-nine members and visitors.

The nomination of officers for the ensuing year was referred to a special committee to report at the next stated meeting.

Dr. Henry Leffmann read the paper of the evening, on "Artesian Waters." The author gave a brief historical sketch of the subject, which was followed by reference to the chemical character of numerous artesian waters from wells in the region about Philadelphia.

Mr. Louis Woolman supplemented the previous speaker's remarks with an elaborate account of the various water horizons of the coastal plain of the Eastern United States. Mr. Woolman illustrated his remarks with the aid of charts, lantern slides, and microscopic slides exhibiting various forms of diatoms and foraminifers found in the strata penetrated in sinking such wells in the region above named.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, December 9, 1899. President James Christie in the chair. Present, twenty-six members and visitors.

The papers of the evening were read by Mr. Edward K. Landis, on "The Tilly Foster Mine," and by Dr. H. M. Chance, on "Some Problems in Deep Coal Mining, with a Description of some New Methods." After some discussion, both papers were referred to the Committee on Publications.

ELECTRICAL SECTION.—*Stated Meeting*, held Friday, December 22d. Prof. Geo. A. Hoadley, President, in the chair. Present, forty-four members and visitors.

The subject for discussion was "Automobiles," and was opened by Mr. Pedro G. Salom.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, December 14, 1899. President Wilfred Lewis in the chair. Present, forty-two members and visitors.

The subject for discussion was "Internal Combustion Engines." The President opened the discussion with a description of the Diesel Motor Among the points that received attention in the discussion which followed were that of ignition before complete compression; the weight and volume of this class of engines as compared with steam engines of equal power; the time duration of firing a charge; and the rate of increase in pressure at the moment of explosion.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, held Friday, December 8th. Prof. Geo. F. Stradling in the chair.

Professor Stradling read a communication "On the Loudness of Sound," which was freely discussed.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.—*Stated Meeting*, held Tuesday, December 5th. Dr. Henry Leffmann in the chair. Present, twenty-two members and visitors. A number of dry plates which had been in possession of Dr. Himes since the year 1884 were presented by him, with the suggestion that they be tested by the members.

Mr. John G. Baker, member of the Branch, exhibited and described an improved device for holding squegee and other dry plates in mounting.

The discussion of the evening, on "Apparatus and Appliances for Microscopy and Photography," was opened by Mr. Fred. E. Ives, who described a number of microscopic accessories which were on exhibition.

A motion was passed directing the Executive Committee to formulate a plan to be presented to the Chemical Section which would secure to the Branch fuller and more independent action. Consideration of the subject was deferred until the Committee should have made its report.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLIX, No. 2. 75TH YEAR. FEBRUARY, 1900

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

EVOLUTION OF TECHNICAL EDUCATION IN ECONOMICS, POLITICS, STATECRAFT AND MORALS; THE WORK OF THE FRANKLIN INSTITUTE DURING SEVENTY-FIVE YEARS.

BY ROBERT H. THURSTON,
Honorary Member of the Institute and Director of Sibley College, Cornell University.

[Commemorative Meeting held in Convention Hall, National Export Exposition, Saturday, October 7th, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

The ideal education of the old Greek who would teach the youth of his country "to speak the truth and to ride a horse," although by no means as comprehensive as the "complete and perfect education" of John Milton, is at least typical of the best thought of the educator of our own time; and especially is it representative, in a way, of the ideals of the advocate of the evolution of the technical

education of people with a view to the preparation of the great body of "plain people" for "the sequel of their lives." The seeking of truths, of facts and data, and of methods of utilization of such truths in the interest of the people, in the promotion of their moral, social and intellectual advancement—of that material progress which underlies all—constitutes real education.

This constitutes a problem for the economist, for the wise political leader and for the statesman of every grade. For the ancient aristocrat and gentleman, honesty and ability to bear oneself as became a gentleman, in all out-of-door exercise as well as in social intercourse with other gentlefolk, were recognized as the fundamental elements of a proper training. Little more was then needed and little more was prescribed. As time went on, not simply the speaking of truth but the learning of truths, not simply the riding of a horse but all manly exercises and warlike accomplishments, were demanded as essential elements of the curriculum of the gentlemen. Later, as the arts of war became less exercised and as those of peace became more and more vitally important with all classes, the clergy of Europe came to dictate the form and extent of the education of the gentlemen and of the well-to-do classes of the time. Even gymnastic exercises as a part of the regular education fell into the background with the drifting out of sight of the arts of war, and the modern, monastic, gymnastic methods of education took shape and controlled all schools. Still later, after political power had fallen out of the hands of monarchs and nobles into the hands of the people, and it had come to be seen that the contemporary education was suited only to the wealthy and aristocratic classes, a new education came into existence, and Bacon and Descartes, Milton and the Marquis of Worcester and Vaucanson sought the development of this field by the introduction of systems of training of the people in such manner as would give them not only a knowledge of language and of literature, of history and of philosophy, but also an acquaintance with the sciences, pure and applied, and with the scientific bases, and even the actual processes, of those arts the prac-

tice of which must, with the great masses, occupy the entire adult and active existence.

In early historic and in prehistoric times, government, so far as developed, was simply a system of forcible control of the masses of the people with a view to the advantage of the ruler and for the purpose of securing for him means of offence and defence in his constant warfare with his neighbors. As time passed and regal power was taken from the hands of the monarch and fell into those of the aristocratic classes, the art of war was cherished largely for the same reasons as those controlling the emperors and the kings of earlier days; although the arts of peace assumed larger importance as wealth and fashion, and the always resultant luxury and effeminacy of the wealthy classes, brought into being a demand for greater intricacy of life and increasing diversification of industries; while the training of skilled workmen has constantly assumed greater and greater importance to the state. The science of economics, the true science of politics and the real and highest duty of statecraft, thus gradually came to be clearly recognized by a few great minds. Comenius and Froebel, Milton and Worcester, Descartes and Vaucanson all saw clearly the real meaning of the Greek ideal for later times, and all did what they could to introduce a broader and a better curriculum and to adapt the scheme of general education more perfectly to the needs of the people. To-day, every thoughtful and well-read and experienced educator sees that a true rendering of the Greek ideal into contemporary form would dictate the education of the people for the life and work of the people, the universal adoption of manual training in public schools, the evolution of a technical side to education, which, coupled with the older gymnastic forms, should give to every ambitious youth opportunity to learn the scientific, the logical and formal, basis of the art into which he feels himself impelled by natural predilection, and sees it should include in its range, not only all the literatures and their languages, all the sciences and their applications, and all the arts of simple accomplishment, but, even more completely and thoroughly, the

arts and vocations of common life, to the extent to which they lend themselves to scientific and logical methods of instruction. Only thus can a truly wise system of education of the people for the life and work of the people be founded.

To-day, the arts of war engage the attention of comparatively few; the arts of peace occupy practically the whole mass of the people. The chief duty of the statesman, of the wise leader in politics, as well as of the economist, is no longer primarily, almost solely, the study of war and of strategy, of diplomacy and of the raising of armies; it is now, rather, primarily and principally the promotion of the business interests of his country, the advancement of the arts of peace, the maintenance of those industries providing the essentials of modern civilizations, the diversification of industries for the purpose of giving larger opportunities and greater industrial and political independence to his own people, and the provision of that education, necessarily largely technical, which best meets the needs of the people as individuals and as a nation.

To-day, the acuteness of the political leader and the wisdom of the statesman may be very accurately gauged by the attention which he gives to the education of the people and especially to a systematic development of that technical education which has so long, but so slowly, been in process of evolution as a complement of the gymnastic, purely literary curriculum of older times. The moral and intellectual magnitude of the educator may be measured by the extent to which he has come to appreciate and to promote these evolutionary movements. The statesmen of Germany, of France, the educators of our own country, particularly, illustrate this fact. Glancing over the compilation of testimony favorable to the inauguration, in the earliest days of our republic, of a national university, as representative of a national and public scheme of education of the people, as printed by the national committee, one sees at a glance that the signatures are those of the greatest statesmen of their time; the grander his statecraft, the nobler his plans for educational development and the larger

the measure of the man in all ways. This has been true from the days of Zenophon and of Herodotus to those of Washington and of Jefferson, and of the founders of German technical education, of our "Land Grant Colleges" and of that Cornellian system which would unite in one great institution systems of education of all men in all studies; such as would prepare the scholar, equally well and with absolutely equal honor, for the rostrum, for the pulpit and for the professor's chair, the lawyer for his courts, the physician for his hospital and for ministration at the sick-bed, the engineer for construction of railroads, canals, bridges and steam-engines and steam-boats, the farmer for all forms of agriculture and the artisan for the workshop, factory and mill. Of these classes, a thousand require scientific instruction where one depends upon literature for his support; hundreds demand a knowledge of the scientific basis of the arts where one needs tuition in language; scores seek professions having a scientific foundation where one can utilize, in later life and for his own personal advantage, the "liberal" education of the so called "learned professions."

Biblical history tells us that, in the eighth generation of the race of Adam, Tubal-Cain was "the forger of every cutting instrument of brass and of iron."* The metal-working trades were thus established, necessarily, at the very beginning of civilization, and apprenticeship, which is technical education, must have become an established system before a vocation could become a trade, before the art of the individual could become the art of a guild. Life in cities could not take form until the trades of the manufacturing industries were fully organized and the age of the cities of antiquity, of ancient India, of Assyria, of Babylonia, of Asia Minor, of Egypt, Greece and Italy, measures approximately the space of time separating us from the beginnings of manual training and of trade-instruction which are, in turn, the foundations of modern technical and professional training. When the great deluge washed away the pro-

* Gen. IV, 22.

duct of the antediluvian industries, the erection of the tower of Babel was the construction, also, of a memorial to the brickmakers of the reviving world. Every modern fundamental profession, trade and vocation probably has a history approximating in its length that of the race itself. Technical education is prehistoric in source, and its history has simply been that of an originally simple and non-scientific, an empirical, system, developing by an evolution, under conditions sometimes favorable, sometimes restrictive, in such manner as to make its progress extremely variable in rate and method from its earliest to its latest phases.

George Ebers, the famous Egyptologist, and hardly less distinguished and certainly more widely known historical novelist,* finds records amid the tombs and pyramids of the valley of the Nile indicating the existence of a great school and college system supported by the Pharaohs, fifteen hundred years and more earlier than the Christian era. For the time, indeed, it was more nearly a true university system than has been seen in Europe since that era, and hardly less universal in its breadth than that inaugurated by Ezra Cornell in the United States of North America in our own generation. Organized in the "House of Seti," in Upper Thebes, it excelled the still older foundations at Heliopolis and at Memphis in its universality, and especially in its extension of its curricula into the fields of technical learning. In its preparatory school, even, were departments of theological, mathematical, legal, astronomical and pedagogical technology. Its great library contained many thousand rolls of papyrus. Schools of art, architecture, sculpture, painting and of engineering, so far as developed at the time, insured the cultivation of the æsthetic with the useful and their union in construction. In magnitude, only Thotmes' great temple exceeded that vast pile. More than this, it was a system of free schools and colleges to which every citizen had a right to send his sons. Dormitories for the young men of the wealthier and noble classes were adjacent, and famous priests guarded and guided the pupils.

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* Professor of Egyptology at the University of Leipsic.

"Scribes"—university professors, free from other labors—were given opportunity for study and research in the highest realms of science, of literature and of art, pure and applied. Its faculty numbered above 800, and there were three "prophets" appointed as directors of its colleges, of whom the high-priest was the senior. Splendid residences were assigned the faculty, and of these that of the high-priest was of unequalled magnificence.

Its successor, the "House of Rameses," was similarly but even more liberally planned, 1300 B.C. The University of Rameses was in existence 1,000 years before the foundation of the later and possibly even greater University of Alexandria.

Technical education finds its earliest, at all complete, records, in the accounts by the Greek historians of the work performed by the technical staff of the great University of Alexandria, during the centuries elapsing between the foundation of that first most complete of universities and its destruction by the Saracens.* When Hero taught mechanical engineering and Archimedes the art of war, when Hipparchus lectured on astronomy and measured the periods of planets and eclipse-cycles, and when disciples of Aristotle gave form to a logical method, technical education took on a distinct form and became recognized as an essential department of instruction. The Alexandrian university was not only the first such great educational organization, but it was, in a true sense, the first university and, for the first time—in fact, for the only time in the early history of education—an institution properly so designated, since then and there, only, in all the course of history, up to our own time, was the endeavor made to offer instruction in all the literatures, in all sciences and in all the arts of the time. Ptolemy, in its foundation, sought to provide what Ezra Cornell aspired to organize—"an institution in which any person might find instruction in any study." Aristotle and his disciples despised no fact and respected all forms of knowledge.

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* "Intellectual Development of Europe," by John W. Draper. New York: D. Appleton & Co.

The "Museum" of Alexandria was the birthplace, as Draper has truly said, of all modern science. Other nations had earlier studied natural science; other civilizations had still earlier produced great schools and great men curious in the observation and study of natural law and of nature's marvellous operations; but it was in Alexandria and in the time of the Ptolemies that we find the earliest adoption of a correct method of scientific investigation and evidences of researches to discover fact and natural law—real scientific research, "the interrogation of nature through systematically planned and prosecuted experiment."

This first and most universal of universities—the times being considered—was founded to promote the acquisition of knowledge in all fields of history, philosophy, literature and natural science, to illustrate the methods of Aristotle, the first philosopher recognizing what we are, in our conceit, prone to designate the "modern" scientific method—first seeking facts, next deducing laws, then constructing a science by the codification of the natural laws thus revealed. The older Greek "philosophy" of the imagination was rejected, and the true philosophy of fact and sound logic and scientific deduction was brought into practice. The speculative philosopher was retired and the experimental philosopher, the scientific investigator, took place in the van. Archimedes investigated the laws of hydraulics; Ptolemy those of optics; Hipparchus gave his contemporaries and his successors, even to our own time, valuable results of research in astronomy; using instruments of precision and making exact measurements as bases for his computations. Euclid created geometry and the world still finds his work perfect. Archimedes' mathematical studies gave him pre-eminence as a leader in his department, and no rival appeared for many centuries, and even up to the time of Newton. In applied sciences, in his discoveries relating to specific gravity, in his inventions of the lever, the screw, the burning mirror, apparatus of war and of peace, he proved himself the first really great producer of the mechanisms and machinery of the engineer and the physicist. Eratosthenes was the great geographer whose

work was the beginning of all that we to-day know, both as to fact and as to system; he founded physical geography. These mighty men of mind recognized the facts of the rotation of the earth, the nature of heat as a form of energy, the general distribution of light and heat, and the variations of climate throughout a spherical earth. So accurate were their astronomical measurements that Ptolemy was able to discover the moon's evection, and Hipparchus the precession of the equinoxes, measuring its period. The motions of the planets were observed and discussed, and Timocharis noted the phases and movements of Venus. Ctesibus invented fire-engines and water clocks: Hero described the first steam-engine, that form which is to-day coming in again, two thousand years after Hero, in the form of the steam-turbine, as a rival of the complicated and costly and imposing machine which is the product of an evolution having a history, as a train of mechanism, of just one century. Sosigenes of Alexandria, in the time of Julius Cæsar, went to Rome to rectify the then confused calendar, and thus this first great university, the prototype of the modern university of our own State, a university without intermediate representative in all these centuries, and which we now recognize as in fact a real and a great technical college, carried its wonderful work through the centuries immediately preceding and succeeding the Christian era.

The Saracen conquest of Egypt resulted in the destruction, in large degree, of this majestic edifice of learning; but the Saracens themselves, once the conquest was complete and they were permitted to settle down to the pursuit of the arts of peace, became inspired with the genius of investigation; the conquerors took up the work of the conquered and we now credit the Arabian philosophers and men of learning with preserving and advancing human knowledge in hardly less degree than did, in the earlier centuries, the Greek Ptolemies and their allies.

The energy of a race is like that of a river, small or great, quiet or torrential, flowing from earlier to later times, compelled by natural forces constantly to follow a general di-

rection determined by the topography of surrounding conditions, to be sure, but always forced to move on until its stock of energy is exhausted. If war demands the expenditure of this energy, it becomes destructive as a mountain torrent in time of freshet or cloud-burst; if peace supervenes, still this energy must find application, and in Egypt, after the close of the Alexandrian campaign, it fructified that intellectual domain as the Nile fertilized the valley which it traversed. Similarly, after the Greek and Roman civilization had been overwhelmed by the Goths and Vandals from the north and by the Saracens in the valley of the Nile, the Arabians diverted their talents into new and useful channels, and the flow of the stream of Saracen energies became subdued to the fructification of the whole of northern Africa and of Spain, and the development of pure and applied sciences among the Ptolemaic peoples was paralleled by that later observed among their conquerors. Destructive energy was replaced by constructive in all departments of human activity. Bagdad became a great cosmopolis in which, far more than in the metropolis of to-day, learning and scholarship and Aristotelian research were encouraged and honored. Haroun-al-Raschid instituted a school in every mosque in the whole Saracen empire, and his successor, Al-Mamum (A.D. 813–832), like the first Ptolemy, built up a great center of learning at Bagdad, collecting great libraries, calling to his court and to his colleges the men of the age, from all countries. His was the Augustan age of the Saracen empire.*

The Saracens boasted that they had produced more poets than all other nations combined; that they developed further than ever had been done before the scientific method now universal; that they substituted a study of nature, of phenomena and fact for speculation; that they promoted mathematics and the exact sciences in a previously unexampled manner; that, in their time, alchemists founded the science and the art of chemistry; that their learned men produced works on mechanics, solid and fluid,

* Draper.

optics and astronomy, geometry and trigonometry, invented algebra and adopted the Indian numeration and figures. They invented all sorts of distilling, filtering, heating and fusing apparatus, instruments of precision for the astronomer, the chemist's balance and the simpler mechanical combinations. They even constructed tables of astronomical quantities, of specific gravities and other scientific reference compilations. The library at Cairo grew to enormous dimensions and is said to have included not less than 6,500 works on astronomy alone. This was a circulating library as well as of reference. The Spanish library of the khalifs is said to have numbered 600,000 volumes, its catalogue filling forty-four volumes. It is said that a physician was compelled to refuse the invitation of a sultan, to Bokhara, because the transportation of his library would have required 400 camels. Another physician, Honian, at Bagdad, maintained a regular business of translations from other languages and issued versions of Plato, of Aristotle and of other ancient learned authors. All then known fields of knowledge and of research were cultivated, an immense literature was developed and all this without let or hindrance, without the slightest censorship on the part of the monarch. All sorts of books of reference were produced, including an "Encyclopedic Dictionary of the Sciences" by Mohammed Abu Abdallah, and colleges dotted the whole extent of the empire. Colleges were then, as now, founded by wealthy men and provided with a permanent income by endowment.* One such college, at Bagdad, with an income of 15,000 dinars, taught 6,000 students of every class, rich and poor, noble and plebeian alike. Free scholarships were provided for the needy and ample salaries for the faculty. Of these learned teachers and investigators Al-Mamum asserted: "They are the elect of God, his best and most useful servants, whose lives are devoted to the improvement of their rational faculties; the teachers of wisdom who are the true luminaries and legislators of this world, which, without their aid, would again sink into ignorance and barbarism."

* Gibbon.

Professional schools were organized; that at Cairo setting the example of stringent entrance-requirements for all who would study medicine, long before the foundation of the European school at Salerno in Italy. In all directions, in the philosophies, in the sciences, in the arts, in all industries, this fund of stored energy of the Saracen race found useful expenditure. The resulting civilization was far more lofty and admirable than was that of Europe during those and for many succeeding centuries. In fact, it was only in the fifteenth century that sufficient liberty was enjoyed by European men of science to permit them to enter freely upon that now familiar field of intellectual occupation, and it was only at the beginning of the seventeenth century, in Europe, that any really notable progress began. Since then the acceleration of the movement has been like that of a falling stone.

Technical learning and the technical and professional schools of the Saracens came into Europe mainly by way of Spain, and the Moslem conquerors of that country made famous their centuries of rule by promoting the arts and sciences in all practical ways. By the tenth century, that country had become a center of learning from which streamed, throughout the continent, the rays of scientific research and the accumulated learning of all the then existing departments of science. The practical outcome was seen in well-built, paved and lighted cities, in heating, ventilating and elaborate furnishing, on a scale and in a manner that even our own time may admire and in some respects imitate. Especially admirable were their systems of social life, with freedom from the elsewhere universal dissipation of the time, with "feasts of reason and flow of soul" in place of banquets of savage character and flow of bowl. Learned men of all countries were ever-welcome guests and Andalusia became the resort of scholars and philosophers, and of men noted for their progress in scientific research, from all countries and all nations and of every race. All were equally welcome and all alike honored. When, in the fifteenth century, the Moors were driven out of the peninsula, the Castilians found a great civilization

well established and the foundations of true learning well laid. The efforts of the anti-scientific parties of the time were never again able to entirely quench this great light; it grew steadily and pervaded not only all of Europe, but all the known world through its stimulation of research, its promotion of inventions and its application of all sciences and all arts in their thus improved state to the development of the best interests of the common people. In this vivification of the germs of our modern civilization, the Jews were particularly active and effective, and this was one of the most powerful influences leading to their later banishment. Their expulsion from Spain led to the distribution of the new civilization throughout the whole of continental Europe, wherever a Jew was admitted.

The Greeks thus carried the torch of scientific learning from their earliest days, its germ antecedent to Aristotle and Alexander by probably centuries, up to the Saracen conquest; the Arabian civilization carried it on into the fifteenth century, effectively cultivating a true philosophy of nature for at least eight hundred years; then came our own modern civilization as developed and evolved in France, Italy, Germany, Belgium, Spain and Great Britain. Its main progress has been observed during the last two or three centuries and its culmination, if culmination there be, has been observed during these last seventy-five years, since the establishment of existing systems of power-production, of transportation and of manufactures—and the inauguration of our recently developed systems of public schooling and higher scientific and technical education.

The study and investigation of mechanical science practically began in Europe with the work of that wonderfully versatile engineer, Leonardo da Vinci, whose biographies, written by men utterly ignorant of his greatest achievements, are devoted to accounts of his painting and sculpture, his verses and his travels and battles and sieges. Leonardo was the instigator of the sixteenth century renaissance of science and the technical arts and profes-

sions.* He was familiar with the Saracen literature and with their scientific work; their books and their learned men having come, by his time, into Italy and the south of France. He adopted research as the only guide in scientific matters, revived the Aristotelian and the Averroesian philosophical systems and applied these true methods to his work in applied mechanics, physics and all the natural sciences with which he, more than any other man of his day, probably, was familiar. His technical applications of the sciences were numerous and valuable and his familiarity with the literature and the science and with the learned men of his time gave currency to his productions that could not otherwise have been attained. He thus firmly founded the existing systems of thought and work in scientific and technical matters. All modern science and all contemporary workers in scientific and technical fields, whether of the schools or of the professions or in research, owe more to Leonardo than the average student can realize.

Finally came Newton and the great mathematicians, Lavoisier and the famous chemists, Boyle and the succeeding physicists, Watt and all the wonderful inventions of our century. By the end of the first quarter of this century the advancement due to all these developments was well under way and that world with which we are concerned took form.

Times have thus strangely changed in these later centuries. In the middle ages and earlier, when all the world was composed of few masters and many men, when the great body of mankind was ruled, and individuality was unknown among nations, even education was directed by the masters of men, and church and state were alike phases of aristocracy. The curriculum was prescribed by monastic rule, and the so-called "four learned professions" were theology ruled by the church, law constructed and manipulated for the monarch, medicine the refuge of younger sons of the rulers, and philosophy the resort of wealthy and aristocratic

* See particularly "Il codice Atlantico di Leonardo da Vinci." Milano. 1898.

idlers. Engineering, the first and last and always essential basis of civilization and of all true advancement in material wealth, the necessary accompaniment of advancement in learning and the promoter of the most vital moral and spiritual elevation, was unrecognized by Greek, Roman and modern European alike, during the centuries preceding the nineteenth. Great mechanics and engineers were deified in the days of mythology, but they were ignored and contemned throughout historic times until our own saw the beginning of a real renaissance of the aristocracy of ideas, of true knowledge and of noblest powers of the mind of man. Individualism and the care of the state for the individual are the practical result of the progress of our own century. The Declaration of Independence and provision for the protection of the inventor are corner-stones in the foundation of the modern and current political creed, and the firm basis of this latest and only true development of the people. It is only when each elementary atom of a population is developed to its highest and best in knowledge, intelligence, independence and character that the great mass, the nation itself, becomes strongest and best. The specific gravity of its elementary molecule is that of the mightiest mass. Give the particles weight and value, and the mass assumes maximum value as a certain consequence. A hundred years ago the schools, the colleges and the universities of even Great Britain were inaccessible to the people of England; those of the continent of Europe were reserved, practically, to aristocracy; in the newly-organized United States of America, only, of all civilized countries, was education practically and legally free to all ranks and all classes. In these United States education was, from the first, recognized as the birthright of the people.

In the Massachusetts Constitution of 1780 it was written: "The encouragement of the arts and sciences and of all literature tends to the honor of God, the advantage of the Christian religion and the benefit of this and the other United States of America." Wisdom and knowledge, as well as virtue, were recognized as essential to the prosperity of a nation, and the cultivation of the arts and sciences, as

well as of literature, was made a duty of legislatures in order that the rights and liberties of the people should be conserved. The great Northwest Territory was controlled by a primary law, the famous ordinance of 1787, in which it was declared that "Schools and the means of education shall be forever encouraged, the perfection of the individual as the elementary atom of the State being the end sought." Later came the slow but still advancing recognition of the necessities of the individual in the perfection of the school system and of the various forms of curriculum required in each grade and in each class of educational institutions. While it seems sometimes questionable whether, with our combinations of masters and of men, of corporations and of trusts, of classes and of masses, the individual is not being again deprived of that liberty and opportunity which seemed on the point of being fully insured him, it is to be noted that, in all these kaleidoscopic movements of the modern world, the individual still retains his right and his power to rise from stratum to stratum, to pass from class to class, to rise or fall, or to swerve from old into new courses, just as readily and just as far as his desires and his natural powers impel and permit. "Liberty always and everywhere insists on the use of all legitimate materials at hand for the attainment of its purposes. Such materials are ability, education, foresight, invention, personal influence and material resources."* Only individual liberty to move in any and every direction in which one's talents, tendencies, interests, proclivities lead can give true progress to individual or to nation. Freedom to secure, not simply an education, but just the sort of education that one's talents and inclinations or one's necessities may seem to call for, is one of the most vitally important of those rights which Magna Charta and the Declaration of Independence have assured to mankind. The placing of schools of engineering beside those of law and of medicine, the rehabilitation of the profession as one of the learned, as perhaps the most learned of, professions,

* "Irresistible Tendencies." President Charles Kendall Adams. *Atlantic Monthly*, September, 1899, p. 293.

the general organization of courses of instruction in the arts and sciences—sciences applied as well as "pure"—and the extension of the school and college systems over the realms of technical, trade and professional instruction and training, have been the most obvious and fruitful results of the liberty of the individual and of the endeavors of our century to promote the interests of the citizen and through him the progress of the nation.

While it is perfectly true that the evolution of education, including those branches which we distinctively call technical, covers a period extending back to the beginning of civilization, if not of human life on this globe, it is none the less true that more has been accomplished during our own century, more during the period of seventy-five years in the history of which we have here and now such special interest, than during the centuries, millenniums, which preceded.

Three remarkable developments of the present century, all the outcome of great social processes of evolution in various departments of our later civilization, have compelled the attention of students of history and of sociology in these later days; illustrating the fact that all modern progress has been made by advances of continuously increasing importance. The rate of progression under the action of the mighty forces which have become so sensible, in these decades which have seen substantially all the grandest movements of humanity, like that of a stone falling under action of gravitation, has been in each of these directions an acceleration. These three most wonderful accelerations have been: (1) the progress of invention and of the mechanic arts; (2) the evolution of modern physical sciences; (3) the advancement of systematic methods of cultivation of the mind. Progress in the mechanic arts and engineering, scientific discovery, and the construction of the sciences, and that form of intellectual training which we call education have all constituted most important characteristics of the progress of the century.

At the beginning of this century the existing educational system had not taken form, and its most striking develop-

ment, the education of a people for the life and work of a people, the supplementing of a purely—and most admirable and most desirable—gymnastic education by technical instruction and professional training in the industrial professions, had not become systematized. Especially is it the fact that the distinguishing characteristic of modern methods of education, classic and scientific, technical and professional alike—the placing of the work of instruction, in every branch of the pantology of modern educations, in the hands of specialists and of experts, of men fitted by special education, by peculiar experience, and by natural proclivities to communicate most of each special knowledge to the pupil—has only now, and even now not completely, come into the accepted platform and constitution of education. A generation ago, even, the proposition that, in education, as in all other departments of human activity, to insure success the work must be performed by the expert worker, was not admitted, and it was not unusual to place in charge of a department, or at the head of a college even, a man having no technical familiarity with the methods of the practitioner, whether mathematician or astronomer, chemist or physicist, engineer or classicist. Clergymen were given the place of the pedagogical expert; lawyers were made heads of schools of engineering; classicists were made presidents of schools of science; and the idea of finding a man fitted by practical experience and natural talent for the position only properly assigned to an expert professional was unrecognized in the general confusion attending the construction and operation of the educational system. To-day all this is changed. Clergymen control the schools of theology, lawyers take in hand the schools of law, and engineers are taking the management of the schools of engineering; and the latest and the least recognized forms of professional school are coming to be known as those exacting most of their students and adopting most extensive and intensive curricula.*

* "Educational Problems. Electrical Engineering as a Profession." R. H. T. (Reprinted from the N. Y. Evening *Post*, September 10, 1898.)

A glance through the pages of history reveals the fundamental thought of the modern and so-called education in the spoken and written words of philosophers of all ages, and its practical embodiment in the school systems has been witnessed, in some degree, at least, from the earliest historic times. The first great university, that which even now stands, its time and surroundings being considered, as the representative university of all time, that founded by the Ptolemies over two thousand years ago, included technical learning and professional training in its curriculum, notwithstanding the anti-utilitarian sentiment of the Greek people and their philosophers and nobles. Astronomy and navigation, mechanics and engineering, mathematics and all then recognized applied sciences were there taught to all students and disciples by the most learned men of the time. The transfer of the arts and sciences and of all learning from Greece to Egypt, and by the Saracens to Spain, and from Spain and the shores of northern Africa to Europe, and through the centuries to our own times, has always been so effected as to maintain technical and professional schools as a part of the system of education of every state, and the organization of the schools at Bologna and at Salerno in connection with the medical and legal professions illustrated, centuries ago, the idea of the modern professional school. The Greek and the Roman and the Saracen and the modern European educations all alike were more than simply gymnastic and "classical;" all included more or less, in varying degree at different periods, the technical and practical side of education.

It was not, however, until the seventeenth century that special and precisely planned technical schools or departments of the university became recognized necessities in the minds of many men, and applied sciences were seen to be the real and ultimate end of the pursuit of the knowledge of the pure sciences, and the gymnastic forms of education to have an ulterior and vital purpose in the promotion of the welfare of the people. Plato had declared education to be the business of the state, and the inference was inevitable that the state should provide that education mos

likely to advantage the people. Milton pleaded for a "complete and perfect" education that should "fit a man to perform justly, skilfully and magnanimously all the offices, both private and public, of peace and war." Bacon had the same thought, and Comenius, his disciple, planned a real "university," to include in its faculty men of science learned in the applications of science in the arts as well as men learned in languages and literatures. The Marquis of Worcester, the inventor of one of the modern steam-engines, the exponent for his time of the truly broad and university-educated man, urged upon his monarch the organization of a system of technical schools for the purpose of promoting the highest interests of the nation; Descartes sought the same result in a similar manner in France, and, in that century, while all the sciences were taking new forms and making new and extraordinary progress through the then new systems of scientific research, the perfection and completing of the educational systems was a prominent thought in the minds of many of the greatest men of the day. Descartes, in fact, proposed a sort of Franklin Institute in which should be provided lectureships and schools for the people, a people's technical university—if that term, thus applied by John Scott Russell, may be admitted—in which the systematic and scientific development of all the educations likely to help the people to prepare themselves for the sequel of their lives should be effected. The foundation of the French "Conservatoire des Arts et Metiers," by the great inventor and mechanic, Vaucanson, was probably the first important actual embodiment of the ideas which had been familiar to Plato, to Aristotle, to the Ptolemies and their successors in the realm of education, in later times. Martin Luther was among these successors, and he and other great German educators early adopted the views of the leaders of thought of the preceding centuries. Germany was the first nation to put in practice the thesis of Plato and to inaugurate, formally and with considerable extent and symmetry, the systems of modern technical education of the people for the life and work of the people, and magnificently, as we may now

perceive, has that nation profited by such wisdom and practical statecraft. To-day the German system of national education is the admiration of the world. It is now a half century since John Scott Russell made his first study of those schools of the people of which he wrote in 1869 so glowing a panegyric.* They have steadily improved and broadened their field from that day to this, and are still improving and maintaining their lead over other nations in many ways, although, if we may accept the judgment of some of their own ablest educators and professional men, our own country has, during the present generation, struck on in advance of them in some departments in methods and curricula. Trotzendorf, Sturm, Neander and Comenius, Spencer and Francke, Basedort and Pestalozzi and Hecker built foundations upon which arose a great system of useful and stimulating education of every class in the community, and in such manner as should give to all the power of making the most and best of every God-given faculty, physical, intellectual and spiritual. This system revivified and regenerated the German nation much as, in these later days, the "land-grant" legislation of our own

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* "Twenty years ago professional duty took me to Germany for the first time. I cannot forget my impression at the sight of whole nations growing up in the full enjoyment of systematic, organized, I might almost say perfect, education. I had already become acquainted with some theories and forms of education. I had read Plato's description of the perfect training for a nation. I was familiar with elementary school-teaching, and enjoyed the privileges of university education and the still higher education of the workshop. I was familiar with the system of Bell and Lancaster, having had personal acquaintance with its authors, and had myself taken an active part in schools of art and mechanics' institutions, but I confess to have been profoundly astonished—I may say humiliated—at the sight of nations whose rulers had chosen to undertake the systematic education of their people, and of peoples who had chosen to bear the burdens and to make the sacrifices necessary to obtain it. I do not know to what men or class of men in Germany the forethought, organization, and patriotism are to be attributed which made them lay aside personal ambition, political animosity, religious sectarianism, and state parsimony in order to unite all the classes of people in a unanimous effort to raise every rank in society to a higher condition of personal excellence and usefulness, and, by diffusing equality of education, to extinguish the most grievous of class distinctions."—"Systematic Technical Education;" John Scott Russell. London. 1869.

country has inaugurated a new system and new views of the needs of the people and the duties of the state. It made evident the fact that, as Russell states the point, the education of the nation is to be divided into two distinct divisions, logically: the one, that which "educates and matures the man, and which we call 'general education;'" the other, that which "specially qualifies the citizen for fulfilling that narrow round of duties which the subdivisions of labor in civilized countries impose on the individual as his special contribution to the commonwealth and which we may call special or technical." In Germany, Russell found, as you or I may find to-day, the most systematic and economical and fruitful, the most "complete and perfect" national organization for the special care of this second division of educational work that the world has yet seen.

When, in our own country, we secure the union of this German national system of administration and this complete distribution of the statesman's care over all classes and in all localities, with our own peculiar and specially efficient system of union of the scientific with the practical, the combination of gymnastic teaching with scientific experimental methods of the laboratory, in all departments and in all technical and professional work, we shall have attained very nearly the ideal of Milton and of the great educators and the real statesmen of our own time. This must soon come. The course of modern progress in this department of national life has been practically one which has a history, as we have seen, dating back to the earliest days of Greek culture; but real progress, with acceleration of measurable degree, really began in the times of Milton and of Bacon, took on importance with the organization of the German national system of technical and professional education in connection with the older gymnastic systems, and assumed visible importance at about the time of the incorporation of the great enterprise whose accomplishments we here and now celebrate. During this century, and particularly since the last generation took a hand in the work, progress has been steady and increasingly rapid. Another generation should see our own country provided

with an educational system, perfect and complete, broad as the continent, deep as modern life and rich and fruitful as the best thought of the wisest educators and greatest statesmen can make it.

Every State and every nation owes to its people the organization of a general system of education—not abstract and ideal, not fitted to the purposes of the well-to-do citizens solely, not planned from the point of view of the older academician or fitted into the ancient monastic scheme—a system adapted to the immediate and practical needs of a great body of civilized people endeavoring to live and work and to enjoy the privileges of modern civilization, on an average income of between $600 and $700 a year for a family, in the settled portions of the country; when this is understood, the question finds easy solution—in words. The difficulties of securing the inauguration, in even our enlightened country, of such a system, in the face of longstanding prejudice, of existing and established curricula of the ancient and cloisteral type, of indifference on the part of politicians filling places belonging to statesmen, of ignorance, on the part not only of the average citizen and voter, but even on the part of the intelligent men of the country, very few of whom have given time to investigation, or thought to this most important of economical subjects, are beyond estimate. These difficulties, however, are certain to be in time overcome, for their removal is essential to the progress of our country in its great career.

The classification may, perhaps, take some such form as this:*

(*a*) A common-school system of general education providing the elementary studies of a good English education, perfecting the pupil in the arts of reading, writing and

* This scheme was substantially constructed as here presented by the writer when, as member of the New Jersey Commission for Devising a Plan for Encouragement of Manufacturing Industries in that State and, as Secretary of the Commission, he prepared for the Commission such a scheme.

See Report of New Jersey State Commission, Trenton, 1878; also *Sibley Journal of Engineering*, June, 1892; "The Demands of the State;" also the *Trans. Am. Soc. M. E.*, 1892, Vol. XIV; and *Trans. Am. Soc. for Promotion of Engineering Education*, 1898; "Organization of Engineering Courses," etc.

arithmetic, at least, and with so much of the most essential primary work in language, geography, etc., as space can be found for, without reducing the vitally important work to inefficiency. This system should be adapted to the needs of all classes.

(*b*) A system of special adaptation of primary instruction to the needs of children who must become skilled artisans and who cannot be kept in school by their parents longer than during the period of their growth to that size and age at which they can be made to assist in the support of the family. Such a system may, perhaps, prove to require special adaptation of text-books to the purpose, in which text-books the terms of the trades, and reading matter giving accounts of industrial processes, may be introduced.

(*c*) A system of trade-schools in which general and special instruction may be given pupils preparing to enter the leading industries, in which schools the principles underlying the principal vocations of the locality are to be taught and the essential actual manipulations of the trades are to be illustrated and taught by practical exercises until the pupil becomes expert.

Thus, the Germans have besprinkled all over their country schools of carpentry, blacksmithing, weaving, bleaching and dyeing, forestry, agriculture, etc.

These schools should be established in every city and town in the State.

(*d*) Polytechnic schools should be incorporated, formally and with system, into the great educational scheme of the State and of the country, in which higher work in the applied sciences and, usually, some trade or professional instruction should be offered students whose circumstances are such that they may be given an education extending toward the years of maturity and whose talents and inclinations lead them to select technical school work as introductory to their later practice of the industrial arts.

(*e*) Technical schools and colleges and professional schools within the colleges and universities, in which the highest professional instruction in the applied sciences and in the scientific basis of the profession may be offered those who

are permitted by rare good fortune to secure a good, a liberal education while preparing for entrance into the professional school and upon their chosen line of life-work.

(*f*) Such a bureaucratic system of supervision and conduct, presumably by the State, acting through experts in all branches of educational work, and all imbued with the Miltonian idea, as will insure symmetry and efficiency of the whole great structure of education of the people for the life and work of the people.

(*g*) In the United States the work of the several States should, it would seem, be correlated by a great central, a national organization, a national university, presumably, to which all lines should converge straight from the most elementary of the primary departments and schools, through the whole system of academic and technical secondary schools and State colleges and universities, and which should thus serve at once as a source of authority and of instructing talent of the loftiest character; providing men of genius and giving grandest educational advantages to all the lower grades; raising up the level to which the tide of culture may rise in attaining the highest possible altitude, and serving, further, as the ultimate goal of the great minds of the nation.

(*h*) National bureaux of education having enlarged powers, wider duties and grander opportunities of engaging in the task of instituting and promoting systematic and general education, such as Milton would have approved, and serving as the great advisory and directing agents in the permanent task of maintaining and improving the symmetry and completeness of the whole national, State and local systems of general and special education.

Supplementing all these, and doing a work that cannot be performed by any system of public teaching in classes and schools, should be found in every city and town such institutions as this in Philadelphia, lending a hand to the ambitious and less fortunate members of the body politic who have been unable to secure the advantages of systematic instruction or who, having neglected opportunities of this sort in earlier life, later are awakened to the desirability of per-

fecting and completing an imperfect and incomplete education.

The grand developments in the direction of the education of the people for the life and work of the people, in these later times, have thus far been :

(1) The institution of the system of common school education in the United States, a system unequalled even now elsewhere, giving to every citizen a preparation for a life worth living, such as no people ever had before.

(2) The organization, first in France, of great technical schools under the supervision of the government, in which the older professional methods of training are adopted in the preparation of youth for the professions of the constructive arts and engineering.

(3) The establishment by Germany, in more complete form, of a system of national schools, manual training, trade and higher technical, such as is represented, in type, by the great Prussian school at Charlottenburg, near Berlin.

(4) The organization of special, isolated, usually privately endowed, polytechnic and engineering schools, like those of the United States and Great Britain, and which are typified by our military and naval academies, the Troy Polytechnic Institute, the Massachusetts Institute of Technology, the Stevens Institute of Technology and the Drexel Institute.

(5) The development of State universities devoted, in fair proportion, to the instruction of students in technical departments and schools under the patronage and care of the State, somewhat after the manner of the common schools—a system which finds its highest development in the Middle and Western States in this country, and which forms part of the whole educational system of the State. The existence of large and privately endowed colleges and universities in the Eastern States has prevented equal development on this side the Alleghenies.

"What is wanted in our day is that complete and perfect representative of one great and all-embracing system which shall, for its time, do what was done by the grandest of all ancient institutions, the greatest of all the ancient

'wonders of the world,' in its day—offer to all-comers opportunity to study and to pursue all the sciences, all the literatures and all the arts of the contemporary civilization. Ezra Cornell expressed the ideas of Plato and of Aristotle and of Milton and of John Scott Russell in a sentence: 'I would found an institution in which any person can find instruction in any study.'

"This Cornellian ambition, absurd as it may seem to the dull plodder in the ways of the mediæval educator and of the monastic regime, is precisely that of the German Empire and of its constituent political elements of the earlier generations, since the time of Luther.

"Once it is recognized as a great principle of politics and economics that the primary duty of the State—given a system of government which steadily maintains the law and preserves the peace—is to see that the people are taught to make themselves competent to make the most of life and of the marvellous opportunities which modern civilization presents to all men, the obvious universality of the scheme of public education and training 'for the sequel of the lives' of citizens is instantly recognized, and its practicability in a reasonable sense as well; for the powers of the State are to be invoked to their utmost limits."*

While common schools, as we know them, were organized in the older States during the colonial period, and in the newer States with the adoption of their constitutions and the formation of their State or even of their territorial governments, it was not until about 1825 that the condition of the country, industrially and politically, had become so well settled that the attention of the people could be given without distraction to the solution of the great problems involved in their thorough organization. Since then our present universal and remarkably efficient common school education has taken shape and has come to constitute the foundation of all secondary and higher education, liberal, classical, even technical and professional. To-day, the

* "On the Organization of Engineering Courses, etc.:" "Trans. Am. Society for Promotion of Engineering Education," R. H. T.; 1898.

whole population of our country is at least educated in the common schools if not in the higher departments of our school and college system. This is the solid and enduring basis of the intellectual and social, and largely even of the moral, life of our nation.

The organization of the great technical schools of Europe, the progenitors of our own technical and industrial schools, may perhaps be properly said to have begun with the inauguration, in 1785, of the French "Conservatoire Imperial des Arts et Métiers," as it is officially called. The establishment was, in 1793, placed in the hands of a "Commission temporaire des Arts," and, still later, the present title was conferred upon it by a decree of the "Convention Nationale." The "Commission temporaire" was fortunately able to preserve the splendid collections uninjured during the disturbed period of revolution in which they had charge of them, and even procured from the Convention a decree making their charge a "depot public" and authorizing the appointment of three "demonstrateurs" and a designer to conduct a course of instruction. A little later, the whole establishment was domiciled in the old priory of Saint-Martin-des-Champs. On its faculty-lists have been numbered many of the greatest names known to France and the world—Thenard, Charles, Darcet, Dupin, Clement, Berthollet, Gay Lussac, Arago, Pouillet, Poncelet, Ollivier, Bequerel, Moll, Alcorn, Tresca, Morin and Laussedat are names familiar throughout the civilized world.

The Conservatoire was not actually constituted a school of technical instruction, however, until 1819, and it has never been a school for the workingmen of France, but has been devoted to the education of students for the higher positions in the industrial system and to the training of professional engineers.

A more typical example of the form of industrial school which is most effective in the development of manufactures and the arts is the later "École Centrale des Arts et Manufactures," founded at Paris in 1829. This school was taken in charge by the government in 1858, and has since that time formed a part of that general system of industrial

education to which France so largely owes her present position as a wealthy and prosperous nation. Students from all parts of France and from other countries as well are admitted. Although large numbers of the students are foreigners, this institution remains, as it was said by M. Morin and M. Tresca, "pour l'industrie, une des forces principales" of France.* Founded originally by an association of scientific men, which included MM. Dumas, Peclet, Olivier and others hardly less distinguished, it stood unaided nearly thirty years, and finally became one of the pillars of the state, and to-day furnishes a large proportion of the civil engineers of France.†

Other schools—as the École Polytechnique, l'École des Ponts et Chaussées at Paris, l'École des Mines at St. Étienne, and that at Alais, l'École des Arts et Métiers at Chalons, those at Aix and elsewhere, and the "Écoles Industrielles" at Mulhouse, Lyons, Lille and in other cities—aid in making the system of industrial education of France admirably perfect. These schools, with the exception of the "Écoles Industrielles," are under the direction of the state.

The trade schools are usually founded by municipal authority, and are under the direction of the city governments creating them. They fit young men to become good workmen and excellent superintendents. They are devoted peculiarly to instruction in the practical operations which constitute the trades. The "Polytechnique," which is, in a certain sense, the highest of the French technical schools, is largely, perhaps principally, a school of mathematics and of the pure allied sciences. L'École Centrale is the highest of the properly so-called industrial schools, and educates leading manufacturers and the directors of great industrial establishments.

The trade schools of Chalons, Aix and Angers were organized by a decree of December 30, 1865, for the instruc-

* "De l'Organization de l'Enseignement industriel et de l'Enseignement professionel."

† Letter from General Morin to Mr. Jas. Forrest, Secretary of the British Institution of Civil Engineering.

tion of all workers in wood and iron, and are only allowed to receive resident pupils, who are selected from among applicants for admission by a competitive examination. The German schools in which engineers or artisans are trained may be reduced to the following groups:

(1) Polytechnic or technical high schools, in which the principles and practice of engineering are taught, sometimes with the aid of a workshop, but generally without it. The graduates aspire to be managing engineers of mines, railroads, manufacturing establishments, etc., each according to his special preparation.

(2) Intermediate technical schools, subdivided into (1) general technical schools, (2) weaving schools, (3) industrial art schools. The general technical schools may be classified into (*a*) higher elementary technical schools, (*b*) secondary technical schools, (*c*) building and mining schools. The graduates of these schools expect to become foremen in shops and works, with the possibility of attaining to a manager's position.

(3) Apprenticeship schools for the training of skilled workmen.

(4) Evening schools, available for artisans. These are attended by men who during the day follow their craft. The "Fortbildungsschulen," or continuation schools, belong in this category.

(5) Trade and professional schools for women.

This classification may be still further simplified in relation to mechanical engineers, foremen and artisans, and all schools devoted to their service will fall under one of the following heads: (1) polytechnic schools, with or without workshops; (2) secondary technical schools; (3) apprenticeship schools; (4) trade schools.

For admission, the polytechnics require sometimes more than the equivalent of an American college course, as the École Polytechnique; sometimes the equivalent of a full course at the Realschule, as at the German polytechnics; sometimes, the best that the preparatory schools can give, as at the Imperial Institute of Technology at St. Petersburg. The range and severity of the requirements for

admission gradually diminish till, in the apprenticeship schools, only the rudiments of knowledge are demanded.

The "Gymnasia" in Germany are preparatory schools for the "Polytechnicum" as well as for the university; but the special preparatory schools for the former are usually the "Realschule."

In Europe, the custom has come to be almost universal to isolate the technical schools from the classical institutions and older universities. This has come about partly through the conviction that better work will be done by each class of college if allowed to work unhampered by the different methods and even the conflicting views, feelings, and traditions of the other, partly, perhaps, in consequence of their different foundations. Many able men favor each system, and the amalgamation of the university and the technical school is likely to be given faithful trial here and there on the continent, and in Great Britain perhaps still more completely; but they are to-day separately administered practically in nearly all cases. The view of the relative importance of manual and of gymnastic training of the mind which prevails generally in Europe is that, in the higher schools of technology at least, the training of the hands constitutes no part of the essential education of the engineer even, and that these schools should confine themselves entirely to the instruction of the student in the principles of his art, avoiding the practice, so far as it involves the use of the hands. It is perhaps a consequence of this belief and practice that the states of Europe have been, for years past, flooded with well-educated, untrained young aspirants for entrance into this vocation who not only have been unable to find employment, but who have, in many instances, been informed by employers that they are not wanted. It is the man who suitably unites theoretical and practical knowledge and training who is wanted and who best succeeds, in Germany no less than in the United States. The view held by so many of the higher schools of Germany and of France is that formerly inspiring the "École Polytechnique" at Paris, the first institution, working on the highest theoretical plane, produced in Europe.

Throughout Germany, technical schools and colleges, and trade schools are distributed so numerously that the visitor from the United States is not only impressed by the completeness of the system and by its universality, but is oppressed by the apprehension that his own country, unprovided with such efficient and essential means of giving to the people a good industrial education, and apparently having few citizens who understand the bearing of that fact upon the future prospects of the nation, as well as upon the character and attainments and upon the happiness and prosperity of the people, is likely to suffer severely when, in the near future, direct competition with this educated and trained nation of artisans shall produce those sad consequences against which history has over and over again warned us.

After their northern neighbors had inaugurated the new systems and methods of education, the Swiss commenced on a similar plan, and established a noble school at Zurich, where they placed some of the greatest instructors in Europe, and opened their "Polytechnicum" to the students from all parts of the world.* More than one-half the pupils are from other countries. The faculty consists of over a hundred professors, assistants and private teachers, and the number of students is above one thousand.

In Great Britain, the government and the people of that country have initiated trade schools and technical and industrial instruction in a few cities, and in connection with such institutions as King's College, the University, and the Crystal Palace Schools, in London; Owen's College, Manchester; Trinity College and others.

American schools, so far as developed in the United States, have been established, usually, by the several States, in compliance with an agreement entered into by them with the United States Government, under the terms of the Morrill Act, of 1862, the "Land Grant Bill."

Three-quarters of a century ago, the people of the United States entered upon one of those periods of renaissance in

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* "Race Education." Sam'l Royce. New York, 1878.

education which, at intervals of a few years, have marked the progress of educational work in this country, and "manual labor" schools were established in many places, in which the college course of education was accompanied by a course of manual labor, either with or without compensation. A "Manual Labor Academy" was opened in 1829 at Philadelphia, which was said to be remarkably successful, the students employing their hours of rest from study in various kinds of bodily work. "Every invalid resorting to this academy in the year 1830 was restored to health."

A number of the States were provided with such schools by legislative action, and in several others, private enterprise did what the State governments had not done in this way. Among others, the Stockbridge Academy, in New Jersey, introduced this change into its program, and Gerrit Smith secured a similar arrangement for New York State at Peterboro.

A report to the House of Representatives of Pennsylvania, in 1832, indicated:

(1) That the expenses of education could thus be reduced one-half.

(2) That three hours' work per day had an important beneficial effect upon the health and strength and in promoting good spirits among students.

(3) That it had an equally useful effect upon the intellectual advancement of students.

(4) That such a system is advantageous in that it aids the impecunious student to obtain advantages in education which are ordinarily enjoyed by the rich only.

(5) That students thus trained make better citizens and more successful men than when not thus physically trained.

The Land Grant Colleges of the United States—of the several States, rather—are the product of one of the grandest examples of statesmanlike legislation that the world has yet seen—one second in importance and fruitfulness to no act of legislation subsequent to the promulgation of the Constitution of the United States. Like all great enterprises having for their purpose the benefit of the people by legislative enactment, this failed of complete success

through the indifference, the folly, or the absolute stupidity of many of those public servants to whom its operation was entrusted; it has, nevertheless, produced incalculable good, both directly, in the foundation and partial support of technical education, and indirectly, and very probably to a vastly greater extent, through its influence upon the States, inducing them to take up and carry on the work from the point at which the General Government left it. It is largely to this legislation that the foundation of the now numerous State universities is due, and the organization of the systems of State education which now more or less completely cover the whole field from primary schools to universities in a large proportion of our States, illustrating the scheme of a complete system of State education to which reference was made, and of which the outline was given in the earlier part of this discussion, more satisfactorily than anywhere else outside of Germany.

The author of the Land Grant Bill, by which colleges of the useful arts were established in every State in the Union at the date of its passage, was Justin S. Morrill, then Senator from Vermont, who introduced the Bill in 1858, and secured its passage by a small majority, only to see it vetoed by James Buchanan, then President of the United States. But the statesmen who sought thus to perpetuate the strongest safeguard of the nation, the effective education of the people, lost none of their interest or enthusiasm, and persevered in their plan, bringing the Bill before the next Congress and the next, and finally they had the satisfaction of seeing this measure become a law during the administration of Lincoln and in the midst of the dark days of the war. "The genius of Lincoln rose to the occasion. With one hand he smote off the fetters of the slave; with the other he joined in a splendid effort to subjugate nature. On the second of July, 1862, while the announcement of emancipation was still on his desk, he signed the Act of Congress donating public lands for the establishment of colleges of agriculture and the mechanic arts."

In most cases the States complied fully with the terms of the Act—some of them more than completely. In the

majority of the States the funds were invested in either State bonds or in a special bond made out for this particular purpose by the State and deposited in its treasury, and the returns were either the prescribed 5 per cent. or something more, in every case except that of the State of New York, which latter State never, until compelled by the courts, complied either in letter or in spirit with the law. Maine and Indiana paid 5 per cent.; New Hampshire, Vermont, Pennsylvania, North and South Carolina and Ohio paid 6, the funds being paid into their treasuries. Massachusetts was the only State in which the fund was divided, most of the State legislatures deciding at once and unhesitatingly that it would be better to hold the fund undivided and to either give it to some existing institution which should comply with the provisions of the grant, or founding an institution, as Cornell University, in the State of New York, in direct compliance with the terms of the law.

The following is a summary of the contributions made to the cause of "education of the people by the people for the people" from the earlier days of the Republic:*

(1) Lands by the township, under Acts of 1787 and 1800, amounting to over 1,000,000 acres, for the support of State universities.

(2) A considerable but unascertained proportion of the money surplus of $28,000,000 distributed to the States in 1836 and never recalled.

(3) A portion of the $3,500,000 constituting the share of education in the total proceeds of land-sales under the Percentage Acts of 1841 and later.

(4) A portion of the 3,500,000 acres accorded by different States to education out of the 9,500,000 acres given by Congress in 1841 for internal improvements.

(5) Further important sums not definitely known, from the sale of over 50,000,000 acres of swamp lands disposed of under provisions of the Act of 1850, from which source

* Blackmar's Report, of 1890, to the Bureau of Education. Hoyt's Report, of 1892, to the Senate Committee on a National University. Thurston's "Technical Education in the United States," "Trans. A. S. M. E.," 1893.

alone the University of California is said to have derived important aid.

(6) Revenues in a number of States from the sale of saline lands, with appropriations thereof to the support of colleges of agriculture and the mechanic arts.

(7) The more than $15,000,000 already derived from the lands accorded to States by the Act of July 2, 1862, for the support of colleges and the mechanic arts; which grant has resulted not only in the establishment of many important technical institutions, but also at the same time in such strengthening of the State universities that some of them are thus early taking their places in the foreground of the great university field.

(8) The appropriation by Act of March 2, 1887, of $15,000 per annum to each State for experimental purposes in aid of scientific agriculture in the broadest sense of that term, a yet further incidental reinforcement of the many State universities.*

(9) The aggregate of over $20,000,000 appropriated for the support of the Military Academy at West Point and the Naval Academy at Annapolis.

(10) The establishment, equipment and support of the Naval Observatory and the purely scientific bureaus of the Government at Washington.

(11) The large sums of money appropriated for the convenience and support of the Congressional and departmental libraries.

(12) The hundreds of thousands expended in buildings for the scientific museums of the Government, and the more than $3,000,000 a year so wisely granted for their support.

Since the date of this report, the nation and various States have annually added hundreds of thousands of dollars to these great sums.

Of the now famous special schools, our U. S. Military

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* The State of New York, as stated in the message of the Governor, for 1892-93, taught in the public schools 1,073,093 children in the year 1892, and 772,426 were either educated in private schools or were not taught at all. The State expended in this work $21,134,516, which was $865,000 more than was paid out, on the same account, in 1891.

Academy was the first to take form, founded as it was in 1802; the Naval Academy was organized in 1845 and both have sustained a high reputation for the excellence of their curricula and the high scholarship of their graduates. The first of the independent schools privately endowed was the Rensselaer Polytechnic Institute, at Troy, N. Y., and its success led to the organization of many other schools of engineering in the succeeding generation. The Lawrence Scientific School was attached to Harvard University in 1847; the Department of Civil Engineering of the University of Michigan was organized in 1852; the Sheffield Scientific School was organized at Yale University in 1847, though much earlier proposed. The Massachusetts Institute of Technology was founded in 1864; Dartmouth College organized its technical departments in 1851 and the Thayer School in 1867. The Worcester Polytechnic Institute took form in 1868 and the Columbia College School of Mines in 1863. Peter Cooper founded the Cooper Institute in 1854 as a mixed educational and trade school and especially for the benefit of artisans and others unable to attend regularly the common and technical schools of regular curricula. The Stevens Institute of Technology (1871) organized as the first American school distinctively and especially devoted to the professional training of mechanical engineers and for the first time recognized that branch of engineering as a profession. The Towne Scientific School of the University of Pennsylvania and the technical departments of Cornell University were organized in 1868, and about 1885 the latter became recognized as colleges under the university organization. Since 1870, there have been almost annually organized and endowed schools of manual training, trade schools and polytechnic and professional engineering schools, until to-day every great city is provided with one or more. Philadelphia and Chicago are peculiarly fortunate in this respect. Nearly every large college or university has nominally, if not actually, professional and technical schools incorporated into its organization and the majority are doing admirable work in these directions. There are, to-day, about 100 reputable technical

and engineering schools in the United States and they annually graduate about 1,000 students into the constructive professions.

The Franklin Institute of the State of Pennsylvania, in its work of promotion of the mechanic arts, has taken no small part in the development of these modern systems of evolution of the Miltonian idea. During the seventy-five years which have, to date, measured its period of useful life it has performed an enormous amount of helpful work in a variety of ways.* Its endeavors have always been effective in the union of science with practice; its membership has always included men of science and men of business, educators and philosophers and great mechanics; its work has always been carried on in fields of applied science with every apparatus of instruction, schools, lectures, systems of research, exhibitions of invention and construction, and all methods of promotion of technical training of young and old, learned and unlearned. The names of Ronaldson, Cresson, Rogers, the Merricks and the Sellers, of Bache and Morton and Wilson, Tatham, Heyl and Sartain, of Jones and Longstreth and Norris and Trautwine and Houston, and many others familiar to the world, have adorned a catalogue of officers and members such as perhaps can hardly be paralleled in any other State or in any other country.

The Institute has established and has carried on all these decades technical lectures, drawing schools, even a high school for a time; it has gathered together a very extensive, unique and valuable technical *free* library and has even published scientific and practical treatises, either officially or indirectly; it has printed, for now over seventy years, its *Journal of the Franklin Institute*, complete files of which have been probably more extensively and for a longer time maintained in the libraries and technical institutions of this country and of Europe than have been those of any other existing publication of its sort on either side the Atlantic.

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* For a detailed account of its work, see "A Sketch of its Organization and History," by Dr. Wm. H. Wahl, Secretary of the Institute; published by the Institute, 1895.

It has even longer maintained a "Committee on Science and the Arts," empowered to examine and report on inventions and advances in the mechanic arts and applied sciences. The files of the *Journal* are rich in contributions of useful and extensively important matter from this committee. Medals and premiums have been offered and awarded for great inventions and improvements in the arts and in mechanisms, and the careful investigation of claims and the selection of worthy objects of such honors by the representatives of the Institute has been of immense assistance in the promotion of the highest material interests of our country. These gratuitous services have never been and can never be adequately appreciated or recognized. These committees and the *Journal* have always been under careful surveillance by the best men of city and State. The editorship of the *Journal* has illustrated this fact, for its list contains the names of Dr. Thos. P. Jones, Alexander Dallas Bache, C. B. Trego, Profs. John F. Frazer, Henry Morton and Geo. F. Barker, Robert Briggs, and two periods of service are assigned to Dr. Wm. H. Wahl, the present Secretary and editor. The Committee on Publication, always supervising the work with conscientious care, has consisted, also, of the best men in the membership of the Institute. It may well be doubted if any journal in the world has a richer list of technical contributions.

The great exhibition of American manufactures of 1824 and its successors have had an immense influence in the improvement of all the arts and manufactures of our country. In that of 1874 more than 200 silver and over 220 bronze medals and 650 diplomas were awarded to as many deserving products of American invention and skill. The electrical exhibition of 1884 probably did more to show what were the prospects of the then infant industry than any other incident or influence of the time. It was the first of its kind, and gave a prodigious impetus to that vocation and those many industries which are to-day grouped within the special field of electrical engineering. The greatest men of science, the most famous mechanics and the ablest manufacturers of mechanism found there attractions and

impressive novelties that had hitherto been to them almost undreamed of. A National Conference of Electricians, then necessarily mainly composed of physicists—for this branch of mechanical engineering had not then taken form as a department of construction or a division of the profession of engineering—was organized, and the officers of the exhibition and this congress, together, laid the foundations of the vast structure now constituting such an imposing division of our industrial system.

Researches like those described in the report of the committee organized to investigate the theory and practice of hydraulic motor construction, in the report on steam-boiler explosions, still an engineer's classic, and in that of the committee investigating the strength of the materials of construction, were at once useful and impressive. A Weather Bureau, even, was organized in 1843, and the later State weather-service and that of the United States may be fairly claimed to have grown out of that first work of this kind. The now universal system of standard screw-threads was the product of the studies of another committee, and the later investigations of water-supply for the city of Philadelphia, of the efficiencies of dynamo-electric machines and of the duration and efficiency of electric lamps, have continued the early-established practice of the Institute into our own time.

All this enormous amount of work in the promotion of the useful arts and applied sciences has been the voluntary service of able men, and not a dollar has been expended for their precious and invaluable time and thought and labor. It may well be doubted whether the history of any country or of any institution gives nobler exemplification of true patriotism.

The work of this now famous institution has not been simply, however, in the departments which have been mentioned; it has done a great work in aiding other enterprises. For a century and more this country, following the lead of its great statesmen of the days of the Revolution and of the early period of our existence as a nation, adopting the principles so admirably expressed by Hamilton and sus

tained by Washington, Jefferson and all their immediate successors, has made the promotion of the industrial arts a primary business in legislation and through executive action. This policy has borne fruit in the institution of a remarkably effective system of patent-law, in the organization of all the essential manufacturing industries and in the advancement of agriculture, directly and indirectly; supplying a home market for its products and giving it machinery which harvests its grain at ten times the rate usual seventy-five years ago, which transports it a thousand miles at less cost to the owner than then for a day's journey to market, and which opens the most distant lands of the trans-Mississippi region to settlement by the sons of the original thirteen States. In this work the Franklin Institute has taken part, and in no manner more effectively than in the inauguration of exhibitions of the products of industry, in the assistance in many ways of the managers of the great International Exhibition of 1876, and the promotion, jointly with the Philadelphia Commercial Museum, of the admirable Philadelphia Exposition of 1899.

The outcome of the policy of Hamilton has been the successful construction of a great system of domestic industries which, now that it has reached its period of maturity, is not only capable of supplying to our own people the cheapest products, the best products and the most abundant, but is also at the same time making compensation to its working people in the highest wages paid in the world, giving them the means of buying more of the comforts and the luxuries of modern life than any other people, while extending the market for the product of each industry and of each producer by making it possible for the members of every craft, and for every individual earning wages, to buy of every other producer. The fact that it is mainly by the payment of high wages to the wage-earner that a market can be made for every product at best advantage has never before in the history of the world been so well illustrated. In this great work of promotion of the whole system of American industries, Pennsylvania, and especially Philadelphia, and particularly the Franklin Institute, has had

efficient part, and the possibility of that novelty—most astounding to the disciples of Cobden and to the practitioners of the Hamiltonian method as well—has arisen from this most successful and well-sustained work of the nineteenth century in our country. An "Export Exposition" in the United States, at the end of a century of, on the whole, steady and consistent support of the policy of upbuilding and maintenance of home industries, is a lesson to the world and one which economists of the ancient sort may well study with profit. Free institutions, the patent system, the protection of domestic trade and manufactures, the consequent growth of the industrial arts, and of manufactures, the resultant provision of a market for the agriculturist, the marvellous stimulation of invention, the growth of a people in intelligence, ambition, productivity and prosperity, which have all come of the enlightened policy of the founders of the nation, are admirably illustrated at this great exposition, the crowning glory of the Franklin Institute and of the merchants of Philadelphia, and may well astonish the world.

Thus the "Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts" continues, after seventy-five years of good work, to do its noble duty more effectively each year. May the work so well begun in our century continue with increasing efficiency for centuries still to come!

THE MODERN WARSHIP,

AS COMBINING IN ITSELF THE HIGHEST RESULTS OF SKILL, INGENUITY AND SCIENTIFIC KNOWLEDGE.

BY REAR-ADMIRAL GEORGE W. MELVILLE,
Engineer-in-Chief, U. S. Navy.

[An address delivered in Convention Hall, National Export Exposition, Saturday, October 7, 1899, on the Occasion of the Celebration of the Seventy-fifth Anniversary of the Franklin Institute.]

Mr. President, Ladies and Gentlemen:

Before proceeding to discuss the subject which has been assigned me, I desire to express the great pleasure I feel in being with you on this important occasion, celebrating as it does the foundation of an institution which has done so much for the advancement of engineering and the mechanic arts. As one whose whole life from boyhood has been spent in connection with one of the branches of engineering, I feel an especial pleasure at being permitted to assist in this celebration. I want also to express my high appreciation of the honor which has been paid me in asking me to be one of the speakers. I do so with added pleasure from the fact that a great deal of the work with which I have been specially associated has been constructed here in your own city, and by men much of whose training in many cases has been due to the Franklin Institute.

The subject which has been assigned me is one of the greatest interest to an engineer, for the modern warship is the complete fruition and triumph of so many branches of the great science of engineering. Although in the ultimate analysis we owe everything to nature, we may well say that in the old wooden ships propelled by sails a very large proportion was due almost directly to nature, with only a minor part played by the artisan and the engineer; while in the modern ship, nature's part is strictly confined to the crudest of raw materials, and the finished product represents, as the title of my remarks so well expresses, the

highest development of skill, ingenuity and science in engineering and the mechanic arts.

Under the circumstances of this discussion, we may be pardoned if, in a retrospective consideration of the subject, we limit our review to steam vessels, for the reason, as I have already remarked, that the part of the engineer (using that term in its broad sense) in the old sailing vessels was exceedingly limited. We shall, by contrast, be enabled to appreciate more fully the wonderful entity which we call the modern warship, if we consider the first one.

It will interest you all very much, I am sure, to know that the first steam war vessel in the world was built for our navy, and was designed by Robert Fulton, who first made steam navigation at all practicable; and the construction of this vessel antedated the founding of this Institute only about ten years. This first vessel was called the "Demologos," or "Fulton the First," and while of what would now be considered very small dimensions, was, nevertheless, a wonder of the period. She was 156 feet long, 56 feet beam and 20 feet deep, measuring 2,475 tons, having a single water-wheel in a central well, and capable of steaming about six knots. The battery comprised twenty guns of the largest size at that date, a number of them having been taken from a captured British vessel. The hull, of course, was of wood, and the boilers were of copper. She was not completed until just after the termination of the War of 1812, so that she never saw any active service, and was blown up by an explosion of her magazine in 1829.

The next steam war vessel, also called the "Fulton," and completed in 1837, was somewhat longer than the first "Fulton," but with less beam, and proved a very successful ship for the period, being capable of steaming twelve knots per hour under favorable conditions. A most interesting thing in connection with this old vessel is the fact that the engineer who designed her machinery and superintended its erection became her chief engineer when she was commissioned, and thereby became the first engineer in the United States Navy. This distinguished gentleman is still alive and in the active practice of his profession. Doubt-

less many of you will at once know that I can only refer to Mr. Charles H. Haswell, known to every mechanic in the United States as the author of "Haswell's Pocketbook." I think we may all take great pleasure in the thought that this venerable and distinguished gentleman, who is not only the Nestor of our profession, but one of its chief ornaments, has been spared to see the growth of the war vessel from the original "Demologos" to our "Oregon" and "Minneapolis," and the merchant steamer, from the original "Clermont" to the "St. Louis" and the "Campania."

After the building of the "Fulton," steam vessels were added to the navy at regular intervals, each class marking an improvement on the preceding ones, until shortly before the commencement of our Civil War we had a class of fine frigates, which in ordnance, machinery and hull were justly considered the finest in the world.

The necessities of the Civil War, of course, gave a tremendous impetus to naval construction, and at this period we have the beginning of the evolution of the modern war vessel. In engineering, as applied to machinery and hulls, several names stand out preëminent at this period, and as strictly germane to my theme I may mention the work of two of them. The Engineer-in-Chief of the Navy during this period was Commodore Benjamin F. Isherwood, an engineer whose practical skill, ability as a designer and high scientific attainments have never been surpassed. One of the problems which he had to solve was the construction of machinery which should be thoroughly trustworthy in the hands of men of very limited experience. This led him, contrary to what would ordinarily be considered good designing, but which, under the circumstances, in my opinion, was consummate engineering skill, to build machinery very heavy, but which, as a matter of fact, never broke down and which carried our guns to victory. In those days, just as in our own, the "man behind the gun" may be most in evidence, but without the "man behind the shovel" he would never have been able to get within range of the enemy.

The destructive career of the "Alabama" had led our

authorities to decide upon the construction of a class of vessels which should be faster than any others afloat, in order that these commerce destroyers might be hunted down and themselves meet the fate which they had so often dealt out to others. Here, again, Isherwood's consummate skill and mastery of his profession showed itself. The material of the hulls was still wood, which gave a platform for the machinery altogether too flexible to permit of the type of engines which we now use; consequently he designed what were known as geared engines, which he, better than any one else, knew were extremely heavy, but the great point is that they enabled him to accomplish exactly what he set out to do. The "Wampanoag," the first of these vessels, in 1868 made the unprecedented record of nearly seventeen knots for thirty-six hours in a rough sea, and for several periods of six hours, seventeen and one-half knots. At that time no other vessel in the world, either war or merchant steamer, approached this speed within three knots.

About this time Mr. Isherwood conducted a number of experiments in connection with the expansion of steam, and boldly enunciated principles which the rest of the engineering world in many cases denounced as erroneous, but which are now accepted as fundamental facts in thermodynamics. This is notably the case with respect to cylinder condensation, as to which he was the first to enunciate the true principle.

Another great engineer became famous at this time, although he had been doing splendid work and helping to develop the war vessel before, namely, Captain John Ericsson. You all know the story of the first monitor, and it is not necessary for me to repeat it. I only wish to remark as apropos of my theme that here was a vessel which in hull, machinery and ordnance was the work of engineers, and which for that period represented the highest embodiment of engineering skill and talent. It is worth noting in this connection that the success of the "Monitor" in her engagement with the "Merrimac" was due almost entirely to the skill of her engineers, Stimers and Newton. They were

thoroughly familiar with every detail of her machinery, which needed skill to keep it in good order, and, as is well known, after the accident to the gallant commander, Worden, Stimers fought the guns while Lieutenant Greene, the executive officer, took command in the conning tower.

I must not neglect to state that splendid work during this period was done for our ordnance; and the development of this branch of engineering, largely due to the skill and ingenuity of Admiral Dahlgren, was such that at the end of the Civil War our naval guns were recognized as the best in the world.

There now comes a period in our naval history which, as far as actual results are concerned, may just as well be passed over, for while our designers were keeping abreast of the times, we were not building anything new in either ships, guns or machinery. Beginning with 1883, however, a new era dawned for the navy and we began the building of our White Squadron, which has so appropriately been termed the "New Navy," and in connection with these new ships I shall endeavor to go into some details which will thoroughly prove the correctness of the theme which has been given me to discuss.

What is the problem that confronts the naval designer? The maximum of offense, combined also with the maximum of defense, and with a maximum of mobility. It is important to note the limitation upon the naval designer as regards one vital element, namely, weight, for this has far-reaching effects in every feature of design, and differentiates in a most marked way his work from that of a designer of somewhat similar works for use on shore.

While it has been aptly said that the war vessel is a "gun platform," and it would therefore almost seem that everything else must be subordinated to securing a maximum gun fire, the vessel must be prepared to withstand an attack of an opponent of equal force, which necessitates close attention to the defensive elements. Now, under the very best circumstances, the weight of the bare hull will approach 50 per cent. of the entire displacement, which, as you know, simply means the weight of the completed ship

with everything on board, so that we have left only somewhat more than half of the displacement for guns, armor, ammunition, machinery, coal and stores. The first problem then is to construct a hull which shall safely carry all the weights, and do so with a minimum amount of material. This is a problem where the skill and ingenuity of the static engineer, for such the naval architect really is, has great room for exercise, and we see it carried out in the disposition of material in shapes which both theory and practice have shown to give the greatest strength for least weight. We see it also in the careful arrangement of frames, keelsons, longitudinal and transverse bulkheads, plating and deck stringers, while the protective deck (popularly supposed to be only for keeping out projectiles) also becomes in the hands of a skilful designer an important element of strength.

The ship must also be unsinkable, or at least as nearly so as possible, and this has led to the subdivision into water-tight compartments, and great ingenuity has been displayed in devising schemes for water-tight doors, which are absolutely necessary to give access from one compartment to another, but which, unless very carefully designed and constructed, may in time of need be a source of danger instead of safety. The latest developments in protection against submersion have taken the form of a belt of cellulose, a material which, when perforated by shot and exposed to water, immediately swells up and excludes a further inrush of water.

Great skill and ingenuity must also be displayed in the proper adjustment of weights to secure correct trim, and this, in connection with the form of the ship, must be such as to give ample stability, combined with steadiness of gun platform. This is an instance where the modern war vessel is a vast improvement on those of years ago, when the question whether a ship would be an easy or a hard roller was almost entirely a matter of luck. Now it is a matter of calculation and design, and the skilful naval architect is able to guarantee a vessel which will withstand any storm, be comfortable as regards motion, and provide a steady platform for the guns.

We may also note in this connection that the modern vessel is a striking example of what ingenuity and skill can do to make habitable and comfortable, compartments that are at best meager and crowded. We ordinarily consider light, water and air as synonymous with what is free and obtainable without effort, yet on the modern war vessel all these elements are due to the skill of the engineer. In place of the tallow candle of our forefathers, we have the electric light; in place of the casks of water many days old and far from palatable, we have absolutely pure and sparkling distilled water—this distilled water has contributed enormously to the excellent health of our crews, as was brought to the public attention in a most marked way during our recent war with Spain, when the crews of our naval vessels had hardly a man on the sick list, while the armies had enormous numbers ineffective. With its numerous bulkheads dividing it into small compartments, the modern war vessel can have no natural circulation of air, and the engineer provides pure air by artificial means. Steam radiators also make both officers and men comfortable in any kind of weather.

As a final item in connection with this branch of the subject, we may mention the remarkable development of scientific knowledge, ingenuity and skill in the prediction and determination of powers and speeds for large vessels from experiments on small wax models. Here we have combined the work of the mathematician and the physicist in working out the laws and formula involved, and the skill of the engineer and mechanician in the design and manipulation of the apparatus.

Turning now to the question of guns and armor, we have a most marked illustration of the accuracy of our theme. At the close of the Civil War our guns were still principally cast-iron smooth-bores. Progress has changed all this into the modern high-powered steel breech-loading rifle, weighing many tons, and driving at immense velocity a projectile whose encounter with an obstacle may be truly likened to that of one of Jove's thunderbolts. The stress coming upon the metal in one of these guns is as great as can possibly

be allowed with safety, and the demands for greater powers have called for all the skill of the metallurgist, combined with the ingenuity and talent of the engineer, in so disposing the metal as to get maximum results with minimum weights. The latest development in these guns, consisting of what is known as the "wire-wound gun," is extremely interesting, as showing how a form of construction, which, at first sight, might seem anything but the best, is nevertheless the disposition of the material which theory shows is most desirable, and practice thoroughly confirms.

It will, doubtless, interest you to hear a few figures of the performance of some of these great guns. The latest authorities state that a 12·5-inch breech-loading rifle, 50 calibers long, and weighing 83 tons, will propel a shell weighing 880 pounds, by a powder charge of 624 pounds, at a velocity of over 2,620 feet per second, giving an energy at the muzzle of over 40,000 foot-tons, capable of penetrating at the muzzle over 45 inches of iron. This energy means that one of our battleships of about 12,000 tons displacement, and which could carry four of these guns, would at a single discharge develop a power sufficient to lift her bodily nearly 15 feet. It can readily be imagined, therefore, what the effect of a projectile from one of these guns would be when striking another vessel at close range.

It is an extremely interesting story to read of what has been appropriately styled the "duel between guns and armor." As fast as one is improved so that its victory over the other seems assured, some inventor comes to the front with an improvement in the latter, which for a time puts it ahead. The armor on our monitors during the Civil War consisted simply of a number of 1-inch plates bolted together. At the present day, a modern projectile would go through such armor as easily as a bullet penetrates pine boards, but long ago it was discovered that a given thickness of armor was much more efficient if rolled in a solid plate, and this was developed until some of the older English battleships had iron armor as thick as 24 inches. The development of the gun soon showed that it was impossible to keep pace with it by mere additions to the thickness of the simple armor,

for a point was quickly reached where it was impossible to carry the necessary weight of armor that would be thick enough. Then came the use of special plates, the compound armor, where a hard face to break up the projectile was welded to a softer back to give the necessary strength. This was followed by steel armor, and then by the well-known Harvey process, which resembled the compound armor in having a hard face with a softer back, but where the plates were made from a single ingot without any welding. The Harvey process enabled an enormously greater resistance to be obtained with a given weight of armor, but even it has been surpassed by the Krupp process, which enables 12 inches thickness to give the same resistance as 15 of Harveyized plates.

In connection with armor plates great skill and ingenuity has been necessary to provide for giving them the proper shape and for enabling necessary machine work to be done on them after they are in position, inasmuch as the hardening process makes it practically impossible to do any work on the face of the finished plates with ordinary tools. Here an application of electricity for giving a local annealing where it was necessary to work with tools enabled the solution of this problem.

The work of the artillerist is not confined to the design and manufacture of the guns and armor alone, but the gun carriages are also important features of his work, and here there has been a great display of skill and ingenuity in devising means for the ready manipulation of these ponderous masses, and the control of the recoil due to the enormous development of energy when the gun is discharged. This is true both of the manipulation by hand and the control of the turntables, or turrets, for the larger guns, and the ease with which a turret and its contained guns, weighing several hundred tons, can be controlled by the movement of a single lever so that the pointing of the gun is almost as simple as that of an ordinary musket, is really surprising.

The chemist also has had an important part to play in connection with ordnance work, in the development of powders which would enable the enormous energy necessary to

be developed with safety to the structure of the gun. With the powder used during our Civil War it would be impossible to get the results of to-day. The development has been through what were known as slow-burning powders down to the smokeless powder of the present, where the saltpetre and charcoal of our ancestors have been displaced by the combination resulting from the treatment of cotton with nitric acid. The difference in the energy of the ordinary slow-burning powder and of the smokeless powder now used can be seen by consulting any table where the two are compared. One which I recently examined showed that guns, otherwise practically identical, required with the same weight of projectile three times the weight of ordinary powder to get the same velocity as with smokeless powder.

We must not forget, while discussing ordnance, the remarkable development of what are known as "quick-firing guns." This, as you know, is really the adaptation to large guns of the kind of ammunition and breech mechanism used on the modern small arms, and it has been carried so far that quick-firing guns are now made of as large caliber as 8-inch, giving a muzzle energy of over 10,000 foot-tons, while the number of times the gun can be discharged in a given interval is about double that of the ordinary breech loader. In the smaller sizes of these quick-firing guns the rapidity of fire is almost incredible, and I remember being particularly struck by the results of repeated trials, showing that it was possible from a six-pounder to have five projectiles in the air at once.

More than a quarter of a century ago what are known as machine guns were introduced; that is, weapons of small caliber approximating to that of ordinary small arms and slightly larger, were so arranged that the ammunition could be fed almost continuously and the rapidity of fire be so great that a single weapon would be equal to a company of soldiers. As you are doubtless aware, the Gatling gun was the earliest of these. These, too, have been developed during the intervening years, until it would seem that finality has almost been reached in the Maxim gun, where, when once started, it continues to discharge itself by the effect

of its own recoil, until the old figure of "iron rain and leaden hail" becomes a simple matter of fact. The Maxim gun will fire 600 shots per minute from a caliber of 0·45 inch or less.

We come now to the machinery of the modern vessel, and I trust that you will pardon me if I go into greater detail here, because this is my own special field and one in which it has been my lot to have been intimately associated with the construction of our new fleet. Here, more than almost anywhere else in the war vessel, the constant demand has been for greater power on less weight, and at the same time the demand has also been for thoroughly reliable machinery that would also be economical.

Progress has been so rapid that it sometimes seems that we hardly have time to get out a design as nearly perfect as possible and see it thoroughly tested in service before improvements have been suggested that render what appeared so perfect relatively obsolete.

Shortly before I became Engineer-in-Chief of the Navy, forced draught had been re-introduced, after many years of disuse. This at once gave an enormous increase of boiler power with a very slight increase of weight, due to the burning of a much larger amount of coal on a given grate surface. The shell boiler was developed until its design seemed nearly perfect, but we were confronted with the problem of getting plates sufficiently thick to withstand the increasing steam pressures in the large boilers and still be able to properly work the plates in our shops. The weight of these boilers was always very great for the power developed, and in the large sizes which they had reached, the utmost skill was necessary for their proper care and maintenance. Shortly before the time had come when further progress with the shell boiler seemed impossible, the water-tube boiler was developed to such a point that it gave us the necessary solution of the problem, and it now seems quite certain that, for some time to come at least, the boiler problem has resolved itself into a determination of the best form of water-tube boiler, inasmuch as we are sure we can construct boilers which will withstand any pressures

that are likely to be used and which are satisfactory in every other respect. These boilers offer almost absolute safety against disastrous explosion, afford a great reduction in weight, and are built to withstand comparatively rough treatment as far as heat is concerned, thus giving freedom from such troubles as leaky tubes and leaky seams, to which large shell boilers were very liable.

The demand for reduction of weights in the engines has been met by the use of stronger materials, and also their disposition in shapes where a given weight of material offers the greatest resistance. We thus have steel castings to replace cast iron; hollow forgings of oil-tempered steel, and the use of bronzes of double the strength of the older compositions. Besides the greater strength of the materials, just as important an item is their much greater reliability. Our manufacturers to-day can furnish us with forgings as to which we know that the results obtained on test pieces will be absolutely true of every part of the whole mass.

Weights have also been greatly reduced by using engines which run at much greater speeds than formerly obtained. This seems a sufficiently simple matter, and yet it was not possible until the improvement came in materials, combined with an accurate scientific knowledge of some of the questions confronting the marine engineer, which had formerly been solved almost by rule of thumb. This is notably the case with propeller design, for it was the mistaken notions on this point that really held down the engine speeds. Inasmuch as the whole office of the motive machinery is to turn the propellers, it might seem that it would be necessary to design the propeller first and make every thing else to suit it; but fortunately, now that we have accurate scientific knowledge of the conditions governing propeller design, we know that the propeller can be arranged to suit almost any speeds found desirable for the engines, and this enables us to choose engine speeds which will give us both lighter and more economical ones than were possible in olden days.

A problem in the design of engines for war vessels, which

is of considerable difficulty, and the solution of which is not yet thoroughly satisfactory, is that of securing economical results at ordinary cruising speeds, with the capacity for the power necessary at maximum speeds. As you are doubtless aware, the power necessary to drive a vessel varies approximately as the cube of the speed, so that if, as is ordinarily the case, the cruising speed is about half the maximum, the power to be developed is one eighth or less of the maximum. As was very cleverly expressed by one of my former assistants (Professor Hollis) some years ago, the problem is like that of having a beast of burden whose maximum power will be that of an elephant, but whose appetite is so adjustable that he could be economically used for work which could be performed by a donkey. You well know that an elephant would eat about the same whatever work he was doing, and while this is not exactly true of a steam engine, it nevertheless is true that its economy, when worked at powers which are so small a percentage of the maximum, is very much reduced. In some of our ships we have tried to solve this by arranging two sets of engines on each shaft, so that at the moderate powers the forward set can be uncoupled. The ill-fated "Maine" had an arrangement whereby the large cylinders of her triple expansion engines could be disconnected, leaving the engines to run as smaller compounds at cruising speeds. A somewhat similar arrangement is in use on the "Nashville," where the large cylinder of a quadruple expansion engine can be thrown out, leaving a triple expansion for lower powers. The objection to all of these is that, if it becomes necessary in an emergency to get full power, it is often impossible to stop to couple up. This was exemplified in a marked way in the case of the "Brooklyn" during the fight at Santiago. She was cruising with her after engines only when Cervera's fleet came out, and it was felt that there was not time to stop to couple up, which would have necessitated from twenty minutes to half an hour. The distribution of the power among more than two shafts offers another solution, which was used on the "Columbia" and "Minneapolis." Personally, I believe that this system, if properly carried

out, would be entirely satisfactory, but it would involve the use of the center screw only for ordinary cruising, and a ship, as you doubtless know, is not so handy with one screw as with two. Our latest design to meet the desire to use two screws and still get relatively small engines for cruising speeds is to use three screws but make the engine driving the center one half the total power, leaving each of the wing screws to develop only a quarter of the full power. We have not as yet built any vessels on this plan, so that, while theoretically we have every reason to anticipate entire success, it has not as yet been tried in practice.

A very interesting illustration of the application of ingenuity and scientific knowledge is the method adopted for balancing the engines so as to avoid vibration of the hull. As engine speeds and hull dimensions increased, there came a combination of circumstances causing excessive vibration of the hull due to unbalanced inertia stresses of the reciprocating parts of the engines. The solution is a very simple adaptation of a type of engine desirable for other reasons with a special arrangement of crank angles and weights of reciprocating parts. The adoption of the steam turbine has also been suggested to accomplish this same object, and turbines have been employed on some torpedo boats. With certain very promising features, there are, however, some great disadvantages, and before the steam turbine becomes a formidable rival of the ordinary type of engine an enormous amount of skill and ingenuity must be exercised, and the lines along which they can act are not yet apparent.

I have already referred to the three vital elements in warship design as offense, defense and mobility, and the best combinations of these features to secure maximum results tax the judgment and experience of the designer, as well as his skill and ingenuity. If time permitted, it would be of the greatest interest to show how the necessity of maximum results in particular items has given us special classes of vessels. Thus in the battleship, which must give and take heavy blows, mobility or speed has been sacrificed, while in the armored cruiser both guns and armor have

been reduced to secure high speed. In the torpedo boat, speed is absolutely vital and everything else is sacrificed to it. The tendency just now seems to be along the line of having only one class of armored vessels which will be very powerful armored cruisers with good armor protection and high speed. This means a vessel of about 12,000 to 14,000 tons displacement, with 8 to 10 inches of Krupp armor, a battery of 10-inch rapid-fire guns, and a speed of about twenty to twenty-one knots.

We have now given a hasty glance at the principal elements of the modern war vessel, although I regret that the limited time at my command has forbidden the consideration of many features which could not have failed to be of interest to you, such as the workshops on board where the necessary routine repairs are made to keep the great machine in working order; the electric installation for lighting the various portions of the ship and providing the searchlights; the elaborate drainage system with the necessary pumps; and the torpedoes, with their wonderfully intricate and delicate machinery, which is so arranged as to work automatically after being discharged from the ship, in a way that would seem to indicate human control at every moment. I trust, however, that you will have heard enough to satisfy you that the theme of my remarks is fully borne out by the facts which have been adduced.

The truth is that in every department of life there has been a tremendous advance, due to the exercise of skill, ingenuity and scientific knowledge, with which the modern war vessel has thoroughly kept pace. A moment's reflection would, of course, make it very clear to us that it would be impossible to build war vessels such as we now possess unless there had been a corresponding development in every other manufacturing industry. Governor Roosevelt, when Assistant Secretary of the Navy, touched upon a very important matter connected with this subject in discussing what was known as the "Personnel Bill." In comparing the development of naval science to the point where it became necessary for every officer in the navy to be an engineer, so that it is necessary for the modern admiral to

know many things of which our great Farragut, for example, was ignorant, he said that it would, of course, require vastly greater skill to handle the complicated mechanism which the modern war vessel is, than one of the old ones, but that, just as we had always been able to produce competent men to handle the less complicated vessels of former times, so without doubt we would get competent men to handle those of to-day. He had learned the fact that the modern warship is a vast engine, and to be properly controlled must be handled by engineers. Congress has in the Personnel Bill provided and directed that, as soon as we can make the necessary arrangements, every officer in the navy charged with the handling of a vessel shall be a trained engineer, and therefore we may be sure that however complicated and delicate the organisms of the machine become, we shall have officers who, by education and experience, are fitted to properly care for the valuable and delicate machines entrusted to them.

I have had a part in two wars, in both of which the navy played an important part and became dear to the people, and I have also passed through the intervening interval, during much of which the navy seemed to be entirely forgotten. I sincerely trust that, as the late war showed we know not only how to build good ships, but also to make them go and to fight them, our fellow-citizens in civil life will see to it that the navy is maintained in a state of the highest efficiency, both as to personnel and material, ever ready for efficient use when needed. In this work, which on both sides is a matter for engineers, this Institute has a vital interest, and I trust that, just as your influence has for seventy-five years been on the side of the general advancement of engineering in the mechanic arts, so it will be on the side of their advancement in the navy.

THE PRESSING OF STEEL: WITH ESPECIAL REFERENCE TO ECONOMY IN TRANSPORTATION. (LOSS.)

DISCUSSION.

(*Concluded from page 40.*)

MR. LOSS:—In replying to the criticisms of Messrs. Christie and Lewis, I desire to say that their main argument referring to the small power necessary for punching as compared to that required for shearing—all as indicated by the experiments—is one that demands careful attention and thought.

When the first efforts showed up this extraordinary result, I could not myself believe their correctness, and in my desire to find the truth, I discarded the entire operating mechanism, building in its stead a complete new device; but the results were identical.

It is difficult to analyze the flow in punching. There is a very distinct side movement of the particles of the metal before any direct severing takes place. This fact was established some years ago by Messrs. Hoopes and Townsend, of Philadelphia, when punching $1\frac{3}{4}$ inches thick material with a $\frac{1}{2}$-inch punch, resulting in a punching of a thickness of $\frac{13}{16}$ inch. The major part of the difference represented side flow. For thinner plates this flow is proportionately very much less, but it still exists.

And again, the quicker the punching process, the less is the flow and the greater is the power required.

Taking it all in all, I am exceedingly glad that these results have been laid before the Institute, as I feel sure that the careful investigation which this subject will now receive from its members will result in establishing the absolute truth, whatever this may be.

It is gratifying to find Mr. Lewis corroborating me in my assertion that *practical* shear is after all only resistance to flexure.

Regarding his reference to the relation between energy and thickness of plate in punching, let me simply state that

the indicator cards were marked as they are, independently of any positive assumed relations.

These particular experiments were just recently made, and hence any mathematical deduction had not as yet been undertaken.

Referring to the greater energy required in shearing with flat knives as compared to the results from those having the blades set at an angle, the indicator cards are all so unanimous as to leave no doubt about this general law.

The greater ultimate with the flat knife is sufficient to more than make up for the shorter cutting stroke made by this particular knife, as compared to the beveled one.

The power required to shear a rectangular bar with flat knives varies directly with the thickness. Of this there is no doubt. As to my reasons for the formula for the ultimate for steel angles, I shall simply refer to my article on this subject in *The American Engineer and Railroad Journal*, May, 1893, where it is covered fully. There is, however, a certain unknown factor connected with this particular part of my work, but whether right or wrong, an intelligent discussion requires the consideration of the data given in the above-mentioned article.

As truly said by Mr. Lewis, any one of the detailed subjects considered here to-night could form a profitable topic for an evening's discussion, and I sincerely trust that my fellow-members of the Institute will help and co-operate with me in the work which I have undertaken, and which to date has been only partly completed.

ERRATA.—JOURNAL FRANKLIN INSTITUTE (December, 1899).

Page 462, line 35, for "six to seven," *read* eight to ten.

Page 465, line 24, for "2,500°," *read* 1,800° to 2,000°.

Page 465, line 27, for "1,800°," *read* 1,400° to 1,600°.

Page 467, line 33, for "2 inches," *read* 1½ inches.

Page 467, line 37, for "Energy per square inch," *read* Energy in foot-pounds per inch of width of bar.

Page 468, in table at top of page, for "inch-pounds," *read* foot-pounds.

Page 468, first line of text, for "2," *read* 1½.

Page 468, paragraph 3, for "The energy per square inch in foot-pounds," *read* The total energy in foot-pounds.

Page 472, line 6, for "our work," *read* the works of The Pressed Steel Car Company.

ICE BREAKERS IN POLAR EXPLORATION.

By Edwin Swift Balch.

Polar exploration, if divided in accordance with the ships employed, may be classified into three periods. The first covers four centuries, from the great voyage in 1596 of the pioneer, Willem Barentz, of Holland, to the building of the "Fram." During this period, ships were almost defenseless against the Arctic ice, and when they were pushed into it, they practically lost all means of independent locomotion, even after the advent of steam. They would be crushed or stay on top, in accordance with the movements of the ice, and in utter disregard of the wishes of the men on board. Curiously enough, however, no one seems to have given any thought to the models of ships for polar exploration. Any old ship was considered suitable for the purpose, after she had received some extra strengthening. Whaling and sealing vessels were not constructed on the best lines to resist ice pressure, for their main object was to permit the stowage of large quantities of oil. Experience gradually fostered the belief that no ship could be devised strong enough to resist a real pressure from the ice in the winter months, even if it might be fortunate enough to escape in the summer ones.

The second period begins and ends with the voyage of the "Fram." This reversed all previous notions on the subject, and proved conclusively that a ship can be built of sufficient defensive power against ice floes, to drift in safety across the Arctic Ocean. The "Fram" was designed * with the idea of making "the shape of the hull such as to offer as small a vulnerable target as possible to the attacks of the ice;" and to build her "so solidly as to be able to withstand the greatest possible pressure from without in any direction whatever." To accomplish these aims, she was

* "Farthest North," by F. Nansen, Vol. I.

built with extremely sloping sides, which enabled her to rise in response to every increase of ice pressure. When the pressure became great, the "Fram" was lifted by the ice and rode on top of it; until, with a diminution of the pressure, the weight of the ship caused her to settle down again.

The third period may be said to begin with an address delivered some time in 1898, before the Russian Geographical Society, by Vice-Admiral Makaroff, of the Imperial Russian Navy, in which he proposed to reach the pole by means of ice breakers. An abstract of his paper was published in the *Geographical Journal* for October, 1898. He succeeded in having a large ice breaker built, not for Arctic travelling, but for commercial purposes, and the story of this ice breaker is told at length in the *Geographical Journal* for January, 1900.

The "Yermak" was built in England by Armstrong, Whitworth & Co., according to the designs of Admiral Makaroff. She was intended to clear the way in winter time through the ice to the port of St. Petersburg, and in summer time to help the navigation to the Siberian rivers flowing into the Kara Sea, barricaded by ice almost during the whole summer. She is a steel ship, with a double bottom and double sides, and is divided into forty-eight compartments. She is 305 feet long, and 71 feet broad. With 3,000 tons of coal aboard, her displacement is 8,000 tons, and in this condition she draws 25 feet. Her bow is inclined 70° from the vertical; her stern is 65°, and her sides are 20° from the vertical. In whichever direction she moves in the ice, she is bound to rise on it and break it with her weight. She has four engines, working four independent propellers, one in front and three at the stern. Each engine develops 2,500 horse-power, so that the total force of the engines is 10,000 horse-power. Each propeller is supplied with an extra auxiliary engine, so that the main engine can be disconnected if necessary; this was meant to save fuel under certain conditions.

The "Yermak's" maiden voyage was from Newcastle to St. Petersburg in the winter time, on which occasion she

forced her way with ease through 160 miles of ice. In June, 1899, under the command of Admiral Makaroff, she was given a trial in the polar ice west of Spitsbergen. After this, she steamed back to Newcastle, where she was strengthened and the forward propeller taken out. On August 6th, she again entered the polar ice north of Spitsbergen. This time she was in the ice two weeks, "covering in that period 230 miles in eighty-seven hours."

No attempt was made at exploration, although it is believed that land was discovered to the northeast, as evidenced by the refraction of the air. The time was devoted to studying the ice, the ship herself, and her behavior in the ice. The trip was, in fact, a shipbuilder's trial trip. In heavy ice, where there was considerable pressure, it took four hours to make 2 miles. In moderately thick ice, the ship made 2½ miles or more an hour. It was found that the conditions of the ice were so different in the Baltic and in the Arctic, that to get the best results in the latter, a special ship would have to be constructed. Admiral Makaroff came to the conclusion that strength of construction was the main point and that even the "Yermak" was not strong enough, but that the engine power could be reduced without disadvantage; in fact, he thought 2,500 horse-power would be sufficient for fairly good progress through the ice. The room gained by reducing engine power could be utilized to carry more fuel, and about this it was also concluded that liquid fuel would be preferable in all respects to coal.

These experimental voyages of the "Yermak" prove conclusively, what was never suspected before, that a vessel may be constructed of sufficient offensive power and sufficient defensive power to force her way through the Arctic pack. The problem of how to penetrate the unknown regions of the Arctic and of the Antarctic appears solved at last. It means discarding the old methods of wooden vessels, sledges, dogs, etc., wherever the sea extends and adopting the resources of the modern naval engineer, of steel, steam and electricity. The change is complete, and the results may prove a lasting benefit to scientific geography.

Franklin Institute.

(Proceedings of the annual meeting held Wednesday, January 17, 1900.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1900.

President JOHN BIRKINBINE in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 18.

The annual reports of the Board of Managers and of the several committees were presented and accepted. (See Appendix.)

Mr. Daniel Baugh was elected to fill the vacancy in the Board of Managers caused by the resignation of George Vaux, Jr.

The Rev. Henry C. McCook, D.D., was elected as an honorary member of the Institute, on the recommendation of the Board of Managers.

A letter was read by the Secretary from Hon. Abram S. Hewitt, acknowledging his election as an honorary member of the Institute.

The tellers of the annual election reported the votes cast at the election; whereupon the President declared the following gentlemen elected to the offices for which they were nominated, viz.:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. O. GRIGGS.

For *Managers* (to serve three years).

ARTHUR BEARDSLEY,	H. W. JAYNE,
HENRY C. BROLASKY,	LAWRENCE T. PAUL,
JAMES CHRISTIE,	HORACE PETTIT,
F. LYNWOOD GARRISON,	OTTO C. WOLF.

For *Members of the Committee on Science and the Arts* (to serve three years).

HENRY F. COLVIN,	JOHN M. HARTMAN,	LOUIS E. LEVY,
THOS. P. CONARD,	CHAS. C. HEYL,	TINIUS OLSEN,
GEO. S. CULLEN,	H. R. HEYL,	LUCIEN E. PICOLET,
CHAS. DAY,	GEO. A. HOADLEY,	GEO. F. STRADLING,
ARTHUR FALKENAU,	HARRY F. KELLER,	W. F. WILLCOX.

Mr. Birkinbine made a communication on "The Engineering Features of the National Export Exposition," which was substantially an informal report on the work involved in the designing and erection of the buildings of the exposition, the details and installation of the power and transmission plant, water supply, lighting and electric service.

Messrs. A. M. Greene, Jr., and C. O. C. Billberg supplemented the President's remarks with explanations relating to the last-named features of the work.

Mr. Wm. E. Quimby, of New York, described and illustrated, with the aid of lantern projections, the construction and operation of the "Screw Pump," which he had devised as a rotary pressure pump. The communication was discussed by Messrs. Fullerton, Eppelsheimer, the President and the speaker.

On motion, the subject was referred to the Committee on Science and the Arts for investigation.

Mr. Arthur Kitson exhibited several of the most recently improved forms of his incandescent oil lamps, and made some explanations respecting their efficiency and practicability in service.

Adjourned. WM. H. WAHL, *Secretary.*

APPENDIX.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

[For the year 1899.]

To the Members of the Franklin Institute.

GENTLEMEN:—In presenting its report of the work of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the Board of Managers congratulates the members upon the substantial evidences of progress, and urges continued co-operation to advance the Institute.

Every committee has been active, and the work accomplished by some of these has done much to advance the work in which the Institute is engaged. The sections have, with generous rivalry, endeavored to excel in the character of papers presented, the discussions upon them, and the renown of those invited to participate in their meetings.

Three new sections were added during the year 1899, and sectional work appears to be a proper method for increasing the usefulness of the Institute, by giving the members the opportunities for close association in special lines of technical work for mutual benefit.

The membership roll has substantially increased, principally through non-resident accessions. Our membership now represents that of a national body —a unique condition for an organization having a permanent local home. In accomplishing this result, the Committee on Membership has been most persistent.

The popular lecture courses provided by the Committee on Instruction have, judging from the audiences drawn to them, proven eminently satisfactory.

The efforts of the Curators to add to the comfort of the members and improve the building have been handicapped by the necessity of deriving revenue from a portion of the building. An effort is being made to remove some of the objections.

Notwithstanding the fact that some of the income from invested funds was not available, the Library makes a better exhibit in respect of additions

than the previous year. This is the Institute's most valuable asset, and it is entitled to receive the most cordial support from our members and friends.

The Library will, in the future, enjoy the benefit of two new funds—that of the late M. Carey Lea and the James T. Morris fund, founded by John T. Morris. Serious consideration is being given to the making of provision for a proper place and arrangement of the large and valuable pamphlet collections, which, up to the present, are practically useless.

The adoption of the book-stack system has proven generally satisfactory, and has also shown its great advantage over the old plan in the preservation of the orderly arrangement of the books.

The Institute has established in the past year a school of instruction in Naval Architecture, which has met with gratifying success, and promises well for the future. If these hopes are realized, its scope will presently be extended to embrace classes in Marine Engineering. The Board considers this departure, in aid of the great and growing shipbuilding interests of the city, as a most important one.

The older schools of Drawing and Mathematics are well sustained, and make a better showing than for several years past.

The Committee on Endowment has prosecuted its work, but has not succeeded in securing the amount desired, the numerous demands upon those able to aid in this effort having hampered the work. The Committee hopes, however, with the assistance of the Institute's members, to accomplish the task which it has attempted.

Two occasions made the year 1899 memorable in the Institute's history. The first of these was the active co-operation of the Franklin Institute and the Philadelphia Museums in the National Export Exposition, held from September 16th to December 2d, which was quite successful. The Department of Awards was conducted by members of the Institute, and the medals and diplomas given will aid in making known the Franklin Institute and its work. The other occasion of importance was the celebration of the founding of the Franklin Institute, which consisted of a public recognition, at the proper date, February 5th, and a Memorial Sermon by Rev. Henry C. McCook, D.D., supplemented by a series of important meetings held in the National Export Exposition Buildings, October 2d to 7th. To each of the sections of the Institute was assigned a part of an evening, and to the Institute, the final session. At these meetings a series of papers of unusually high order were presented by men who are recognized as authorities in their respective specialties.

The proceedings of the seventy-fifth anniversary week will be published, with some incidental historical matter, in the form of a separate "Memorial Volume," which is now being compiled by the Secretary.

During the year the Institute was also recognized by its President serving, by invitation, as a member of the committee to unveil the statue of Benjamin Franklin presented to the city of Philadelphia by Mr. Justus C. Strawbridge.

The Franklin Institute has passed its seventy-fifth year. Its next notable anniversary will mark a century of useful work. What the Institute will be in 1924 will depend largely upon the membership of to-day. It is probable that a majority of those now on the rolls will have passed away before the Institute is one hundred years old, but each of us may do his or her part

towards making the future as memorable as the past, by maintaining the present activity, and giving to the work our best endeavors and our personal interest.

There is much to encourage in the record of the past years ; there is much to be done in the years to come.

The record of membership, the resources, liabilities, receipts and expenditures, the details of the work of committees of the Institute and of the Board, also those of the Committee on Science and the Arts, and the reports of the various sections, are appended for the information of members.

By order of the Board.

JOHN BIRKINBINE,
President.

PHILADELPHIA, January 10, 1900.

MEMBERS.

Members at the close of 1898	1,850	
Number of new members elected who have paid their dues in 1899	389	
		2,239
Lost by death, resignation and non-payment of dues,		88
Total membership at the end of 1899		2,151

FINANCIAL STATEMENT FOR THE YEAR 1899.

Balance on hand January 1, 1899	$62 62
Receipts from all sources	18,609 88
	$18,672 50
Payments for all accounts	18,564 69
Balance	$107 81

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1899, consist of the following :

(In the hands of the Institute.)

Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894	1,755 00	
		$18,755 00

Brought forward		$18,755 00
(In the hands of Elliott-Cresson Trustees.)		
*The Elliott-Cresson Medal Fund (approximate)		4,729 55
(In the hands of the Board of Trustees of the Franklin Institute.)		
The Legacy of George S. Pepper	$38,562 50	
The Legacy of Eugene Nugent	1,000 00	
Legacy of Emeline B. Nicholson	1,520 00	
The Edward Longstreth Medal Fund	1,000 00	
The Donation of an Unknown Friend	5 00	
The Donation of Sigmund Riefler	20 00	
Life Membership Fund since October 1, 1894	1,750 00	
Journal Endowment Fund	138 00	
Special Endowment Fund	1,105 00	
James T. Morris Memorial Fund	1,000 00	
By the will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $100 or more per year, equivalent to a capital sum of	2,000 00	
		48,100 50
		$71,585 05

* Figures for 1899 are not at present accessible. Last year's amount is therefore substituted.

ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1899

To the Board of Managers of the Franklin Institute.

GENTLEMEN:—The Committee on Instruction is able to report that the same arrangements respecting its popular lectures as have been in operation for several years, with the co-operation of the Young Men's Christian Association, have remained in force, and that the outcome has proved mutually beneficial and satisfactory. The Committee has been able, as in former years, to secure the voluntary services of a number of distinguished lecturers, whose co-operation in contributing to the work of the Institute should be recognized by a suitable expression of thanks.

The very large attendance of members at these popular lectures has fully demonstrated that they meet a demand which the Institute is justified in recognizing even at greater cost than they now entail. Also, the problem of the differentiation of the popular from the strictly technical work of the Institute, now conducted successfully through the sections, is thus satisfactorily solved, and without friction.

As to the school work, the Committee may report substantial progress during the past year.

The number of pupils attending the Drawing School was 231, showing an increase, as compared with the previous year, of forty-five.

Thirty pupils were enrolled in the Mathematical School, which may be said to have only come into active existence in 1899. The outlook for this school is considered to be distinctly encouraging.

The experiment was made last year of aiding in the organization of a School of Naval Architecture, on the strong representations of Mr. Chas. H. Cramp that a school of this kind, under the patronage of the Institute should prove highly beneficial to the many apprentices and young men engaged in shipyards in and about Philadelphia. The undertaking has thus far amply justified this opinion. Although it has been in operation but a few months, there were enrolled at the close of the year thirty-six pupils. Should the participation of pupils continue to grow in accordance with expectations, the scope of the school will, in time, be extended to embrace the allied subject of Marine Engineering.

The Committee desires here to express its appreciation of the zealous and efficient work of the Directors in charge of the schools.

WM. H. WAHL, *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY FOR THE YEAR 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1899:

	Bd. Vols.	Unbd. Vols.	Pphs.	Chts.	Lithogr.
Additions—By Gift	764	318	1957	3	1
From Com. on Pub.	25	9	5		
Moore Fund	143	20	37	4	
Mem'l Library Fund		2			
General Fund		1			
Lea Fund	13	1			
Binding	268				
Exchange	15				
	1,228	351	1,999	7	1

Total additions for the year 3,586

An increase of 660 over 1897 and 749 over 1898.

Total number of volumes January 1, 1900 50,348

Total number of pamphlets January 1, 1900 35,545

The Library also contains 2,807 maps and charts, 642 designs and drawings, 1,222 photographs, 191 newspaper clippings, 26 manuscripts.

Binding—Periodicals, reported among the additions	268	vols.
Old Books	10	"
Moore Fund Books	6	"
Memorial Library Books	3	"
Rebound	1	"
Repaired	5	"
	293	

Exchanges.—Four hundred and eighty-seven societies and publications were on the exchange list of the *Journal* during the year 1899, an increase of twenty-eight over 1898.

The Library, in its new fire-proof steel stack, has been open with great satisfaction and continuously throughout the year. But the entire satisfaction is short-lived, for the increased numbers of public documents that are coming to the Library make it evident that during the coming year already there will be lack of room for proper accommodation. The British patent collection also is growing so rapidly that it is impossible to give shelf-room to the last two shipments received. Moreover, the 35,5co and odd pamphlets, an extremely valuable part of the Library, still lie practically useless without shelving in the third story of the part of our building that is not fire-proof.

Two plans have been proposed for obtaining the additional accommodation so pressingly required, and as they are both so inexpensive, only needing an outlay of a few hundred dollars, your Committee strongly urges that both may be authorized. One of the two plans was urged in our last annual report, namely, the use of one of the two front rooms on the lower floor of the building. That room has now been vacated by the former tenant, and, even if it should be desired to use it for the Institute purposes, the walls would give place for a considerable number of volumes or pamphlets. The other plan is to add another story to the book stack itself, by cutting off the Seventh Street end of the present drawing school.

Proper accommodation for the invaluable collection of drawings and charts is still lacking, as reported last year.

The binding has been continued, and if the appropriation of the past year for the purpose can be renewed the coming year, and if, at the same time, the unexpended balance of last year's appropriation can also be used, very satisfactory progress can be accomplished.

The main addition of books has been, as in former years, from special gifts during the year, and next from the volumes of serials received in exchange for the *Journal*.

The older book funds, the Moore Fund, about $750 a year, and the Memorial Library Fund, about $50 a year, have supplied a smaller number of volumes than usual. The Mathew Carey Lea Fund, amounting to about $150 a year, has now just begun to add its quota. The James T. Morris Fund has, by the liberality of Mr. John T. Morris, just been doubled, that is, increased to $2,000, and is expected to yield about $100 a year, and to begin to be usable at once.

The Library Committee has worked zealously and harmoniously, with well-attended, spirited meetings. Different branches of applied science are now represented on the Committee, but all have mutual consideration for the claims of the others, and aim at the filling out of a well-balanced library.

BENJ. SMITH LYMAN,
Chairman Library Committee.

PHILADELPHIA, January 8, 1900.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN :—The statistics of the operations of the Committee on Science and the Arts for the year 1899, herewith appended, present a highly

creditable record of the Committee's activity during the past year. Its comparison with the records for the year immediately preceding appears distinctly favorable and encouraging, as evidenced by the following general summaries:

Cases pending at the beginning of the year:

1898	32
1899	42

New cases from all sources:

1898	59
1899	56

Cases finished during the year:

1898	47
1899	63

Cases pending at the close of the year:

1898	44
1899	35

Thus, the number of cases pending was one-third greater at the beginning of the past year, and one-fifth less at its close than the corresponding statistics of the year before.

Again, the number of investigations completed was one-third greater for 1899 than for 1898.

The number of medals awarded, of all classes, presents a like aggregate, namely, ten, although the Elliott Cresson Medal was not conferred in a single instance during the year just closed.

In view of the numerous cases that are now being referred to this Committee by the Bureau of Awards of the National Export Exposition, it may confidently be expected, apart from other reasons, that the Committee is now entering upon one of the most fruitful years of its honorable existence.

In closing his connection with the Committee, in the relation of its presiding officer, the Chairman desires to express his appreciation of the courteous consideration extended to him at all times, and his personal thanks to the Secretary for his valuable and efficient aid, always cheerfully rendered.

EDGAR MARBURG,
Chairman Committee on Science and the Arts.

ANNUAL REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1899.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on Meetings has held regular sessions as prescribed by the by-laws, and has arranged for the presentation of nineteen communications. Of these, a number have appeared in the *Journal*, and others have been deemed sufficiently interesting to warrant their reference to the Committee on Science and the Arts.

The attendance at the stated meetings during the past year has shown

some improvement, indicating the maintenance of interest on the part of the membership.

Respectfully submitted, on behalf of the Committee,

WASHINGTON JONES,
Chairman.

PHILADELPHIA, January 10, 1900.

ANNUAL REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS, 1899.

To the Board of Managers of the Franklin Institute.

GENTLEMEN:—In transmitting to the Board of Managers the annual reports of the several sections, the Committee on Sectional Arrangements desires to express its gratification that the policy to which the Institute has lately committed itself, of establishing sections for the benefit of its members as rapidly as the need for them became apparent, has demonstrated its utility in the most unmistakable manner.

Following closely upon the organization of the Mining and Metallurgical Section in 1898, two new sections were founded in 1899—the Mechanical and Engineering Section and the Physical and Astronomical Section; and the Chemical Section found it desirable to extend the scope of its operations by the formation of a Photographic and Microscopic Branch, which, to all intents and purposes, represents a third new section set in operation during the past year.

The large number of members who have attached themselves to these new centers of activity in the Institute, and the very general interest manifested in their meetings, furnish the best evidence that could be desired to prove that the members of the Institute are prompt to avail themselves of the opportunities afforded by the new sections to meet for mutual benefit.

Every new department thus established strongly adds to the advantages which the Institute affords to its members, and enlarges the scope and value of its work as a technical society, and the Institute has reason to be well satisfied with its progress in this direction during the past year.

Several projects for new sections have been under advisement for some time, but on account of the diversion of interest and attention to the conduct of the Exposition, they have not been pressed to realization. During the present year, however, your Committee confidently expects that they will be carried into effect.

The Institute has now in active operation five sections, viz.: Chemical Section, Electrical Section, Mining and Metallurgical Section, Mechanical and Engineering Section, and Physical and Astronomical Section. All of the older sections show substantial gains in membership, and all exhibit a degree of activity that promises well for the future.

The Committee has heretofore expressed the desirability of attracting a larger number of young men toward the Institute, and with that intent, the grade of Junior Associates was created; and the subjects discussed before the Mechanical Section have usually been popular and attractive in style. This project has not been fully developed, and it is believed it could be extended by a personal canvass. Possibly the creation of a section especially devoted

to the interests of the Juniors might be useful, as a similar system has proved highly effective with the engineering societies in New York.

The Committee would recommend this project for the consideration of the Board, as it is believed to offer a most promising field for the future usefulness of the Institute.

JAMES CHRISTIE, *Chairman.*

January 5, 1900.

ANNUAL REPORT OF THE CHEMICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Chemical Section has maintained an unimpaired activity during the past year. Meetings have been held regularly, and the papers and discussions presented, of which the more important have appeared in the *Journal*, were fully up to the standard of the work previously done by the Section.

During the past year the need for affording the members an opportunity of cultivating certain collateral branches of science caused the Section to expand its facilities by the creation of a branch devoted to photography and microscopy, which has maintained a creditable state of efficiency.

The combined membership of the Section and the Branch, at the close of the year, is 162.

The Section held an interesting joint meeting at Bethlehem, Pa., in May, with the Lehigh Valley Branch of the American Chemical Society.

The Section also participated actively in the ceremonies attending the celebration of the seventy-fifth anniversary of the Institute.

The Institute is now beginning to realize the income of the Lea Fund, for the purchase of books relating to chemistry and physics, and the Section last year recommended to the Library Committee the purchase of a number of valuable reference works with the available income, in accordance with the committee's action requesting the Section's aid in the premises.

The list of authors, and the titles of communications presented and subjects discussed at the meetings of the Section and the Photographic and Microscopic Branch, are hereto appended.

"Methods for the Examination of Explosives." Dr. W. J. Williams.

"The Clarification and Purification of Municipal Water Supplies." Mr. Allen Hazen.

"A Process for Testing Metals." Mr. Joseph Richards.

"The Laboratory Production of Asphalts from Animal and Vegetable Matters." Dr. Wm. C. Day.

"The Development of Pneumatic Chemistry." Dr. H. C. Bolton.

"On Series in Spectra." Prof. E. A. Partridge.

"The Use of Iron in the Purification of Water." Dr. Thos. M. Drown.

"The Two-Circle Goniometer." Dr. Joseph W. Richards.

"A Historical Sketch of Methods for the Liquefaction of Gases." Dr. H. F. Keller.

"Artificial Graphite." Dr. Wm. H. Wahl.

"The Relations of Chemistry to the Progress of the Arts." Dr. Harvey W. Wiley (Anniversary Address).

"The Influence of Science in Modern Beer Brewing." Dr. Francis Wyatt.

"Artesian Waters." Dr. Henry Leffmann and Mr. Lewis Woolman.

"An Improved Stereoscopic Camera." Mr. John G. Baker.

"The Systematic Application of the Microscope to the Detection of Adulterations of Food" (discussion).

"The Making of Photography." Dr. Chas. F. Himes (Anniversary Address).

"The McDonough Process of Color Photography." Mr. Frank V. Chambers.

"The Organization of Photographic Record Work" (discussion).

"An Improved Device for Holding Squeegee and other Dry Plates in Mounting." Mr. John G. Baker.

Exhibition of Accessories to the Microscope, including, especially, the Polariscope and Spectroscope.

JOSEPH W. RICHARDS,
President.

ANNUAL REPORT OF THE ELECTRICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Electrical Section has had a successful year, if interest in, and attendance on its meetings, is any criterion.

The membership at the beginning of the year was 116; and at the present date it is 140, showing a gain of twenty-four for the year.

Not only have there been interesting papers for each meeting, but also the members have shown their interest in them by vigorous discussion.

The papers read at the meetings have been as follows: Meeting of January 20, 1899, W. H. Tapley, of the United States Government Printing Office, at Washington, D. C., "Practical Application of the Electrical Motor to Printing Press Machinery." February 28th, demonstration evening, Prof. W. S. Franklin, of Lehigh University, showed and described some forms of the Nernst Lamp that he had made; he also showed that heated glass is an electrical conductor by sending a current of 2,000 volts A. C. through a glass tube after heating it with a Bunsen burner. The current resulting from this voltage melted the tube.

Mr. Elmer G. Willyoung showed the construction and operation of the electrolytic interrupter, in connection with a coil and X-ray tube. Mr. Balderston, of Williams, Brown & Earle, exhibited a new form of static X-ray machine in operation.

March 28th.—Mr. Frank Sprague, of New York, "The Multiple Unit System of Electric Traction."

Mr. Albert B. Herrick, of New York, "The Electrical Inspection of Street Car Equipment."

Mr. Edward E. Higgins, of New York, "Some of the Transportation Problems in Larger Cities."

Mr. Charles Hewitt, of the Union Traction Company, of Philadelphia, opened the discussion on the preceding papers.

April 25, 1899.—Prof. R. A. Fessenden, Western University of Pennsylvania, Alleghany, Pa., "The Design of Electro-Magnetic Mechanism."

Prof. J. Henry Klinck, of Lehigh University, Pa., "A Photometric Comparison of Illuminating Globes."

May 19th.—Mr. Jas. Hamblet, of New York, "Electric Clocks Historically Considered, and the Uniform Distribution of Time." Mr. J. D. Darling, of Philadelphia, showed an improved form of primary battery (Harrison cell).

July 20th.—In place of the regular meeting at the Institute an excursion to Lincoln Park, by boat, was attended by about thirty members.

October 3d.—At the National Export Exposition, in honor of the seventy-fifth anniversary of the Franklin Institute, addresses were delivered as follows:

Dr. Edwin J. Houston, "The Seventy-fifth Anniversary from an Electrical Standpoint." (Anniversary Address.)

Mr. Ralph W. Pope, of New York, "Influence of Technical Societies in Promoting the Progress of the Electrical Arts." (Anniversary Address.)

November 24th.—Mr. F. W. Willcox, of the General Electric Company, Harrison, N. J., "Incandescent Lamps and Filaments." Mr. Walter E. Harrington, Camden, N. J., "Rail Bonding."

December 22d.—Discussion of the subject "Automobiles" by Messrs. Morris, Salom, Marks and Roche.

In conclusion, I wish to congratulate the Section on its prosperous condition and its opportunities for future growth and activity. I wish also to express my personal appreciation of the efficient work of the Program Committee, to whom, more than to any one else, the success of the year is due.

GEO. A. HOADLEY,
President of the Electrical Section.

REPORT OF THE MINING AND METALLURGICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Mining and Metallurgical Section has to report, in connection with its operations during the past year, a substantial gain in general interest in its work on the part of its members.

There were presented during the year 1899, fourteen papers, some of a high order of excellence, and all of interest.

The membership at the close of the year is eighty-six.

The Section took an active part, as the representative of the Institute, in the work of the International Association for Testing Materials, having named a committee of five members to act in its behalf in furthering the objects of the Association. This committee also took an active part in the work of the American Branch of the Association, which is now well advanced.

In May, the Section united with the Chemical Section in a joint meeting with the Lehigh Valley Branch of the American Chemical Society, held in Bethlehem, Pa. The event proved to be one of much interest, embracing a visit of inspection to the works of the Bethlehem Iron Company, the Government Ordnance Works and the Lehigh University.

The program of the Section for the current year is filled for the greater portion of the meetings, and the general character of the papers to be offered is such as will fully sustain the reputation of the Section as a live and growing branch of the parent tree.

Appended hereto is a list of papers read in 1899:

"Segregation in Steel Ingots." Mr. A. W. Allen.

"The Mogollon (N. M.) Mining District." Dr. H. M. Chance.

"The History of Malleable Cast Iron Manufacture in the United States." Mr. George C. Davis.

"Klondike Region." Professor Angelo Heilprin.

"Iron Ores of the Oural Mountains." Mr. H. B. C. Nitze.

"Notes on the Reduction of Iron Ores." Mr. John M. Hartman.

"Subterranean Ice Deposits." Mr. Edwin S. Balch.

"Titaniferous Iron Ores." Prof. J. F. Kemp.

"Some Features in the Structural Design of Buildings." Prof. W. H. Burr.

"Riddles Wrought in Iron and Steel." Mr. Paul Kreuzpointner.

"The Development of the Iron Mannfacture in the United States." Mr. John Fritz (Seventy-fifth Anniversary Address).

"Three-quarters of a Century's Progress in Mining and Metallurgy." Mr. Charles Kirchhoff (Seventy-fifth Anniversary Address).

"The Annealing of White Cast Iron." Mr. Chas. James.

"The Tilly Foster Mine." Mr. Edward K. Landis.

"Some Modern Methods of Deep Mining." Dr. H. M. Chance.

JAMES CHRISTIE,
President.

ANNUAL REPORT OF THE MECHANICAL AND ENGINEERING SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—Although the Mechanical and Engineering Section may be said to have only entered upon its career at the beginning of the year 1899, its brief history has abundantly confirmed the excellent judgment of its founders, not only by the circumstance that its membership is considerably larger than that of any of the other coördinate branches of the Institnte, but also by the large attendance at its meetings and the very general interest which these meetings have attracted.

The policy adopted by the Section from the beginning of its career was, as far as possible, to avoid formality and to promote and encourage the free interchange of opinion among its members, with the view thereby of insuring the active participation of the large number of mechanics in the membership of the Institute, whose interests it was felt by the organizers of the Section should be considered as paramount to all other objects.

To interest this class of its members, the Section wisely decided from the start to devote its meetings largely to the discussion of debatable subjects of importance to mechanical experts, and to invite the freest discussion of them by the members and others. The wisdom of this policy has been abundantly confirmed.

The following subjects were discussed during the year at the Section meetings:

"Travelling Cranes."

"The Mechanical Applications of Compressed Air."

"Internal Combustion Engines."

"The Construction, Operation and Maintenance of Pumping Machinery."

"Hydraulic Transmission, Valves and Packing."

In addition to these, the Section devoted two meetings to the presentation of the following communications:

"An Engineer's Experience on the United States Repair Ship 'Vulcan,' with Admiral Sampson's Fleet," by Prof. Wm. S. Aldrich; and a paper on "The Flow of Steel," by Mr. Henrik V. Loss.

The Section also participated in the ceremonies of the celebration of the seventy-fifth Anniversary of the Institute, in the Convention Hall of the National Export Exposition, on which occasion the President made an introductory address, and was followed by Dr. Coleman Sellers, who gave an admirable address on "The Progress of the Mechanical Arts in Three-quarters of a Century."

The membership of the Section at the close of the year 1899 is 192, and with the gratifying results already attained, it is confidently hoped and believed that in this Section a new and important field of usefulness has been added to the Franklin Institute, which will continue to grow and yield an abundant harvest.

WILFRED LEWIS, *President.*

ANNUAL REPORT OF THE PHYSICAL AND ASTRONOMICAL SECTION, 1899.

To the Committee on Sectional Arrangements.

GENTLEMEN:—The Physical and Astronomical Section was organized on February 8, 1899, on the petition of eighteen members of the Institute.

On May 19th, following, the inaugural meeting was held in the lecture-room, in the presence of a large and interested audience of members and friends. The proceedings embraced an inaugural address by Professor Cleveland Abbe, of the U. S. Weather Bureau, "On the Relation of the Mechanic Arts to Physics and Astronomy." Addresses were also made on the occasion by Dr. A. E. Kennelly, President of the Section; Prof. T. C. Mendenhall, President of the Worcester Polytechnic Institute, Worcester, Mass.; Prof. A. S. Mackenzie, of Bryn Mawr College, Bryn Mawr, Pa.; Prof. L. d'Auria, and others.

The Section has since held regular monthly meetings, as prescribed by the by-laws of the Institute, at each of which one or several communications of interest have been presented and discussed.

A list of these is appended hereto.

The organization of a section of the Institute devoted to pure science emphasizes in the most convincing manner the recognition which the Institute has always given to the fact that all the advances made in the arts have their origin in the cultivation of science for its own sake by original investigation, and exemplifies that union of "science with practice" which it has ever been the aim of the Franklin Institute to represent.

The list of communications presented at the meetings held in 1899 is as follows:

"Methods of Determining the Gravitation Constant." Prof. A. S. Mackenzie.

"The Daguerreotype and the Action of Light upon Silver Iodide." Dr. E. A. Partridge.

"The Florentine Enigma." Dr. G. B. M. Zerr.

Introductory Address, Seventy-fifth Anniversary Celebration. Dr. A. E. Kennelly.

"Some Notable Contributions of American Physicists during the last Three-quarters of a Century" (Anniversary Address). Dr. T. C. Mendenhall.

"Loudness of Sound." Dr. Geo. F. Stradling.

"The Coördinates of the Center and Radius of a Circle and the Angle of Intersection of Two Circles in Trilinear Coördinates." Mr. Jesse Pawling, Jr.

"The Aberration Constant." Dr. G. B. M. Zerr.

A. E. KENNELLY, *President*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, January 3, 1900.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted :

Graphophone "Grand."—Thomas N. Macdonald, Bridgeport, Conn.

The subject of this investigation is a modification of, and improvement upon, the graphophone, a method and apparatus for recording and reproducing sounds, invented by Chichester A. Bell and Sumner Tainter, of Washington, D. C. The report embraces a historical summary of the evolution of sound recording and reproducing machines, and a scientific analysis of the modes of operation of the several types of these machines.

The report is reserved for publication *in extenso*.

The investigators award to Mr. Macdonald a Certificate of Merit, and to Messrs. Bell and Tainter they recommend the award of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—Louis E. Levy, Chairman; J. M. Emanuel, H. R. Heyl, Samuel Sartain.]

Levy's Acid-Blast Process of Etching Metal Plates.—Louis E. Levy, Philadelphia.

ABSTRACT.—The invention consists in the application of an atomized spray of acid or other eroding agent, which is projected vertically upward by means of an air-blast against the surface to be etched, and in a certain combination of appliances for effecting this object.

The invention is covered by letters-patent in various countries, those of the United States bearing date of October 12, 1898.

For details of the method and apparatus reference is made to this *Journal*, **147**, 337. (ART. Levy—"Acid-blast Process for Etching.")

The inventor has made several improvements in details since the reading of his paper before the Institute, at the stated meeting of February 15, 1899, the most notable of these relating to the making of efficient provision for preventing the heating of the plate and the acid during the etching operation.

The report finds that the claims of the applicant respecting the several advantages of the process are substantially correct, and after an examination of

all accessible records, the conclusion is stated that the process and apparatus are original with him, and in view of the importance of this invention, and in consideration of the originality of the idea and of the ingenuity displayed in its application, the award of the Elliott Cresson Medal is recommended. [*Sub-Committee.*—Frank E. Manning, Chairman; George H. Buchanan, Samuel Sartain.]

The following reports were considered:

System of Oil Heating and Incandescent Lighting.—Arthur Kitson, Philadelphia.

Water Heater for Range Boilers.—Adam Heller, Baltimore, Md.

Pneumatic System for Preventing the Bursting of Water Pipes.—N. Monroe Hopkins, Washington, D. C.

Braiding Machine.—Andrew V. Groupe, Philadelphia.

These were held under advisement.

SECTIONS.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH (CHEMICAL SECTION).—*Stated Meeting*, Tuesday, January 2, 1900. Dr. Leffmann in the chair.

Mr. John G. Baker described an apparatus and method which he had devised for entitling negatives, and exhibited several lantern slides to demonstrate the utility of the invention. The subject was discussed by Messrs. Sartain, Ives, Leffmann and the author.

The subject announced for discussion, namely, "Micro-photography and Photo-micrography," was then announced by the chairman, who defined the proper significance of these terms, which are frequently, but improperly, used interchangeably. The distinction was emphasized by the exhibition of specimens. Special attention was called to the utility of micro-photography as a means of preserving, in convenient, transportable form, valuable and bulky records, manuscripts, etc.

A recess was taken to permit of the inspection of the exhibits with the aid of the projecting lantern and table microscope. The discussion was participated in by Messrs. Keeley, Baker, Ives and Leffmann.

The Executive Committee, to which had been referred the question of the reorganization of the branch as an independent Section, reported in favor of the change, and was authorized to carry the proposition into effect, in co-operation with the parent section. W.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, Friday, January 5, 1900. Prof. L. D'Auria in the chair.

The following communications were presented and discussed:

"The Co-ordinates of the Center and Radius of a Circle, and the Angle of Intersection of Two Circles in Trilinear Co-ordinates." By Jesse Pawling, Jr., and the "Aberration Constant." By Prof. G. B. M. Zerr.

The following officers were elected for the current year: President, Dr. A. E. Kennelly; Vice-Presidents, Prof. L. D'Auria and Prof. Geo. F. Stradling; Secretary, Prof. E. A. Partridge; Conservator, Dr. Wm. H. Wahl. W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, January 10, 1900. Mr. James Christie in the chair.

Prof. F. Lynwood Garrison read a paper on "The Lead and Zinc Ores of Southwestern Missouri." The author devoted his attention specially to the lead and zinc deposits in the region commonly known as the Joplin district. He described their geological relationships, and dwelt at length on the topographical and other surface indications by which the presence of the ores is supposed to be shown. The paper concluded with a general historical sketch of the development of this mining district, the methods in vogue for the mining and treatment of the ores, statistics of production, etc. The paper was well illustrated with the aid of ore specimens, lantern slides and diagrams. Some discussion followed.

The following officers were elected for the current year: President, Mr. Joseph Richards; Vice-Presidents, Dr. D. K. Tuttle and Mr. A. E. Outerbridge, Jr.; Secretary, Mr. G. H. Clamer; Conservator, Dr. Wm. H. Wahl. W.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, January 11, 1900. Dr. Wahl in the chair.

The subject for discussion was "The Heating and Ventilation of Workshops and Factories." Opened by Mr. Walter B. Snow, of Boston.

Mr. Snow described, and very freely illustrated, with the aid of the lantern, the blower system, as applied in its most modern aspects to industrial establishments and other large buildings.

An animated discussion followed.

The election of officers was postponed until the next stated meeting. W.

CHEMICAL SECTION.—*Stated Meeting*, January 16, 1900. Dr. W. J. Williams in the chair.

Prof. Robt. H. Bradbury presented a paper on "Racemism," which was an elaborate *résumé* of the present scientific views entertained on this highly interesting subject.

A report was presented by Dr. Keller, for the special committee named to consider the proposition of the Photographic and Microscopic Branch to sever its connection with the Section and form an independent section. The report favored the change.

The following officers were elected for the current year: President, Dr. W. J. Williams; Vice-Presidents, Mr. Lyman F. Kebler and Mr. Joseph Richards; Secretary, Mr. Wm. H. Ridenour; Conservator, Dr. Wahl.

A vote of thanks was extended to Dr. Joseph W. Richards, the retiring President, for his zeal and ability in the Section's interest during his term of office. W.

ELECTRICAL SECTION.—*Stated Meeting*, January 23, 1900. Mr. C. J. Reed in the chair.

The following officers were elected for the current year: President, Prof. W. S. Franklin; Vice-Presidents, Messrs. Joseph Richards and Geo. T. Eyanson; Secretary, Mr. Richard L. Binder.

The paper of the evening was read by Prof. John Price Jackson, State College, Pennsylvania, on "Electrical Machinery for Use in Coal Mining." The subject was profusely illustrated by means of lantern slides.

The thanks of the meeting were tendered to the speaker.

Adjourned. W.

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CHEMICAL SECTION.

Special Meeting, held Tuesday, January 30, 1900.

WHAT IS PARIANITE?

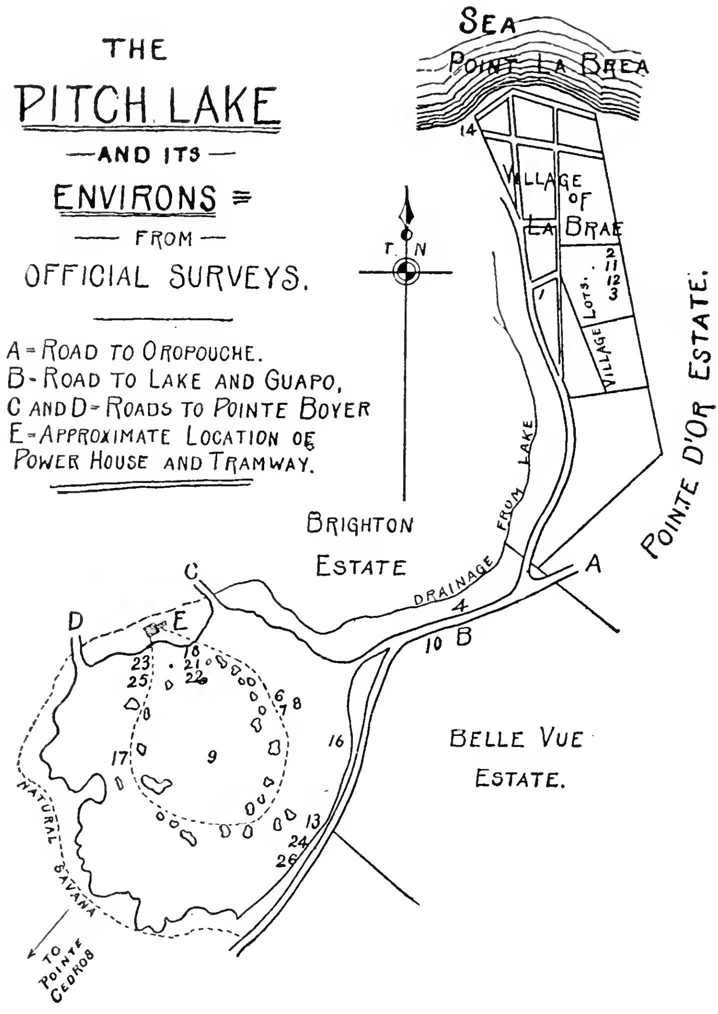
BY S. F. PECKHAM.

When Trinidad pitch is treated in such a manner as to separate its proximate principles, and thus reveal its chemical structure without decomposing them? This is the question that I propose to attempt to answer, and while I admit that the answer is incomplete and inadequate, I contend that I have entered a course of investigation that will ultimately lead to conclusions that will be final.

THE SPECIMENS.

The specimens used were those collected by myself in 1895. They were fully described in the paper published by myself with Miss Laura A. Linton, in the *Am. Jour. Science*, for March, 1896. The description of their location relative to each other and to the lake is thus given from that paper:

No. 1 was picked up at random from the pitch taken from an excavation from which the cargo of the bark "Ella" was dug, during February and March, 1895. The



excavation was upon a village lot about three-quarters of a mile from the lake towards Point La Brea.

No. 2 is from a village lot, which we have named the "Photograph Lot." It was here that a pit was dug and

photographs taken of the pit at intervals of ten days to determine whether any movement in the pitch was in progress by which a cavity dug in the pitch would refill. No. 2 was taken from the pitch removed from the pit. This lot had been excavated about six months previous and had nearly refilled, and was then being uncovered preparatory to the removal of a fresh supply of several thousand tons. The pit refilled 40 per cent. of its dimensions in ten days. It was about 20 rods nearer Point La Brea than No. 1.

No. 3 is so-called "Iron Pitch" from the Photograph Lot. This is pitch that has been melted and deprived of its water and gas. It is solid, of a bluish-black color, with a dull earthy fracture, and is slightly sonorous when struck.

No. 4 was taken from a lot on the right-hand side of the road approaching the lake, that was being excavated by Mr. Ghent. It came from a point 10 or 15 feet below the surface on the western border of the mass filling the ravine down which the overflow of pitch from the lake has taken place, and nearly on the opposite side of the road from the point from which No. 10 was taken.

No. 5 is No. 4, boiled to form Épureé, in Mr. Ghent's boiling works near Point La Brea.

Nos. 6 and 7 were from opposite corners of a mass about 12 inches square and 4 inches in thickness. This mass was taken from a point on the northeast side of the lake on the outside of and near to the tramway, and was selected of convenient size from among a quantity that had been broken with a pick preparatory to removal in the tram cars or carts by the Trinidad Asphalt Company.

No. 8 is from an average from the same piece made up by breaking fragments from many points upon its surface.

No. 9 is from the center of the lake or near it. The mass was soft enough to flatten in the shade, but did not stick to the paper in which it was wrapped. After drying, it became rigid and brittle.

No. 10 is an average from a large piece taken from an excavation being made by the Trinidad Asphalt Company

on the Bellevue Estate near the road leading to the lake. The excavation extended along the road for, perhaps, 1,500 feet, and was narrow. The pitch was clean and pure, but was covered by rank vegetation that grew upon and in the pitch itself, and not upon soil that covered it. This fact accounts for the high percentage of organic matter not bitumen, although the piece was taken several feet below the surface.

No. 11 is a decomposition product of the pitch from the Photograph Lot.

No. 12 is another decomposition product from the same lot. It resembled coke and may have been heated. It is the only material resembling coke that we saw in or around the lake and the amount was only a few pounds.

No. 13 is also a decomposition product resembling No. 11 from the south side of the lake. It was enclosed by a pellicle of sun-dried, melted pitch, within which it was of a light brown color with a columnar structure, like starch, and was very easily powdered.

No. 14 is from a pile of land pitch melting on the beach of Point La Brea, said to have come from the same lot as No. 1.

No. 15 was brought from the lake about 1865, by the late William Atwood, of Portland, Me.

No. 16 is from the southeast side of the lake inside the road, and was cut from the surface at a spot free from vegetation. The point was about halfway from the tramway to the border of the lake.

No. 17 is from the west side about midway of the tramway loop, where men were loading tram cars. It was picked up from under the feet of the men.

No. 18 is iron pitch, on the northeast side of the lake near where the left limb of the tramway, looking south, enters upon the lake.

No. 19 is refined land pitch, from the refinery of the Trinidad Bituminous Asphalt Company, at Jersey City, N. J. It came from the same lot as No. 2.

No. 20 is refined lake pitch, purchased in New York of the Warren-Scharf Company.

No. 21 is from the northeast side of the lake near the left limb of the tramway looking south.

No. 22 is from the northeast side of the lake near the right of the left limb of the tramway loop looking south, about 100 feet from No. 21.

No. 23 is from the northwest side of the lake on the west side of the right limb of the tramway loop looking south.

No. 24 is from the south side of the lake near where the road leaves the lake.

No. 25 is from the northwest side of the lake on the west side of right loop of the tramway looking south near a "blow hole."

No. 26 is from the south side of the lake near where the road leaves it, about 100 feet from No. 24.

No. 27 is Épureé from the boiling works of the Trinidad Asphalt Company, at Point La Brea. It was made by boiling a mixture of Nos. 10, 8 and 9.

Nos. 6, 7, 8, 9 and 17 represent commercial lake pitch.

Nos. 16, 21, 22, 23, 24, 25 and 26 represent the contents of the lake occupying the annular space outside the tramway and embracing hundreds of thousands of tons.

Nos. 1, 2, 4, 10 and 14 represent an average of commercial land pitch.

Nos. 5 and 19 represent refined land pitch.

Nos. 20 and 27 represent refined lake pitch.

Nos. 3, 11, 12, 13 and 18 are rubbish as far as commerce is concerned, and are introduced here to show that there is rubbish in the lake as well as outside of it, and also the relation of alteration products to the commercial pitch. The locations of the several specimens are shown on the accompanying map.

It will be seen that these specimens consisted of five each of commercial lake and land pitch, seven from the annular space between the tramway and the circumference of the lake, a specimen each of iron and chocolate pitch from both the lake and the land, a specimen resembling coke, a specimen of refined lake and land pitch, two specimens of Épureé, and a specimen brought from the lake by William Atwood about 1865.

THE METHOD OF ANALYSIS.

As is the case with all other methods of chemical investigation, the investigation of bitumens, as at present conducted, represents a growth. The starting-point is the classical research of Boussingault, first described in 1837. (*Ann. de Chem. et de Phys.* (2), LXIV, 141.)

It must be remembered that this research was undertaken more than sixty years ago, when organic chemistry was in its infancy as compared with to-day, and when the methods of investigation with which the chemists of to-day are familiar were unknown. It detracts nothing from the value of Boussingault's work to say that it is worthless as a guide in modern research.

I have found by years of experience that solid bitumens cannot be investigated by ordinary methods of distillation. Trinidad pitch, either lake or land, is decomposed when heated to a temperature of 100° C. with a copious evolution of hydrogen sulphide. Whether or not this reaction would attend distillation in vacuo I do not know.

The methods of analysis by solution remain. Why should objection be made to them? Why are they not analytical? I really do not know. Solution may certainly be properly considered a chemical reaction, and the more solvents that can be applied to a solid with clearly-defined results that can be repeated with accuracy, the more complete must be the method of analysis. To dissolve a bitumen in carbon disulphide, which is a universal solvent for bitumens, does not analyze the bitumen, although it may separate the bitumen from its impurities; but to subject a bitumen to the action of several solvents in succession, by which the bitumen can be referred to a distinct class, is a valuable analytical process.

These considerations have been impressed upon my mind during the several years last past, in which I have been attempting to arrange a process of analysis that shall apply to all bitumens, and enable the analyst to distinguish, both alone and in mixtures, the several varieties of bitumen, in a manner similar to the schemes that have been proposed for alkaloids or other organic compounds.

Parianite may be regarded either as an emulsion of gas, mineral water; bitumen, that is, compounds of carbon, hydrogen and nitrogen, oxygen and sulphur, any or all of the last three, with organic matter not bitumen, and mineral matter consisting of silica and clay as impurities; or, it may be regarded as an emulsion of gas, water holding mineral salts in solution, bitumen as above described, with complex organic salts of iron, alumina, lime and magnesia, with ulmic and, perhaps, other peat acids, with ferrous sulphide, and silica, some portions of which are in combination with the other ingredients and the remainder free. Either alternative exhibits a very complex substance, but each quite unlike the other. By what means can it be determined of what the mixture really consists? Certainly not by any process that separates a hypothetical substance called petrolene and a second called asphaltene, a third called organic matter not bitumen, and a fourth called mineral matter. One might just as well *analyze* a log of wood by burning it into smoke, flame and ashes.

THE GAS.

We will begin at the lake with the gas. I visited the lake on Point La Brea on four different days, and practically walked all over the deposit, both inside and outside the lake. I did not once recognize the odor of hydrogen sulphide. When I was in California in 1865, it was stated that the big spring on the upper Ojai plateau discharged carburetted hydrogen. I found the gas would not burn, and then I gathered some of it and found it was nearly pure (carbonic acid) carbon dioxide. I suspect that the greater part of the gas discharged from the lake is also carbon dioxide. It is the normal product of the deoxidation of the sulphates contained in the lake water, as sulphuric oxide yields more oxygen than is sufficient to convert the bases present into carbonates. No doubt the deoxidation of the sulphates in the water is attended with a variety of reactions resulting in a variety of chemical products, of which both carbon dioxide and hydrogen sulphide form a part. The proper place to investigate these gases is at the lake.

THE LAKE WATER.

Mr. Richardson has fully investigated the lake water, and in his report of 1892 he gives his results in great detail. The water used by him was taken from the water floating on a kettle of melted pitch that was being refined. It was probably more highly concentrated than lake water, and had, perhaps, lost some of its volatile ingredients. He gives the following analytical results:

IN 1 KILOGRAM.

	Grams.
Cl	6·7757
SO_3	5·5409
SO_2	·0467
S_2O_7	trace
H_2S	"
S	"
SiO_2	·0688
B_2O_3	·0117
I	·0008
Br	trace
P_2O_5	none
Na	6·5149
NH_4	·4071
K	·3391
Li	·0271
Ca	·5280
Mg	·2666
Fe	·0720
Al	trace
Mn	none
Cs&Rb	"
Organic	·4901
Oxygen	none
	21·0896

It is probable that these results *indicate* but do not represent the composition of lake water. They also *indicate* the composition of the water saturating the pitch. This water, examined by Mr. Richardson, has an acid reaction.

In the paper recently published by Mr. Richardson (*Jour. Soc. of Chem. Industry*, January, 1898), he gives an analysis of water from a spring that arose in the pitch:

IN 1 KILOGRAM.

	Grams.
Specific gravity	1·0599
Solids at 110° C.	82·100
Sodium, Na	27·193
Potassium, K	0·528
Chlorine, Cl	38·210
Sulphuric acid, SO_3	3·207
Calcium oxide, CaO	trace
Magnesium oxide	0·506
Carbonic acid, CO_2	3·700
Silica, SiO_2	0·222
Organic matter	?
	73·566

From these analyses it appears that the lake water is rich in chlorides and sulphates of sodium and iron, with iodides, bromides and borates, in the first instance, and carbonates in the second.

AQUEOUS SOLUTION OF THE PITCH.

One hundred grams of No. 8, which is a fine specimen of commercial lake pitch, were digested with successive portions of distilled water at a temperature of 60° to 70° C., until there was no longer a reaction for either Cl or SO_3. The first portion contained a large amount of ferrous sulphate. The solution, on standing, deposited a small amount of ferric oxide. The solutions were concentrated to 1 liter and portions of 100 cubic centimeters were evaporated over a water-bath. The residue contained chloride and sulphate of iron and sodium. Probably a larger portion would give reactions for all the soluble salts obtained by Mr. Richardson from lake water. This residue also contained a small amount of organic matter that was not determined. The percentage of this residue was 1·135 per cent. of the pitch.

THE ALKALINE SOLUTION.

It is impossible to visit the pitch lake without observing that an immense amount of partially decayed vegetation is entombed in the pitch. Enormous stumps are uncovered, with trunks and branches of trees in every stage

of decay, from solid wood to large masses of humus that a kick will scatter, precisely as if they were found in the peat of a bog. This humus becomes kneaded and incorporated with the pitch precisely as is the mineral matter, and, what has not been properly recognized, the humus on a colossal scale has formed those peculiar compounds, the precise natures of which are but little known, but which Mulder, Boussingault and others have referred to amides and double salts, in which ammonia, the peat acids and iron, and especially alumina, are combined into exceedingly complex compounds, insoluble in water, but readily yielding to solutions of alkaline hydrates and carbonates. These reactions are brought together from many researches and admirably treated by Prof. S. W. Johnson in his "How Crops Feed," pp. 276–280, to which the reader is referred. The treatment there recommended to be applied to soils for the determination of the humus compounds has been applied to this sample of Trinidad pitch with the most satisfactory results, and a flood of light is thrown upon the problems presented by these unique and complex substances. 4·9325 grams of the dried residue, which represent 5·000 grams of air-dried pitch, were digested in successive portions of a solution of dry sodium carbonate, 5·3 grams to 1 liter of distilled water. The first portion was colored as dark as port wine and the last portion was uncolored. The alkaline solution was acidulated with hydrochloric acid and the precipitated ulmic acid was collected on a balanced filter, dried at 100° C. and weighed. The ulmic acid represented 1·542 per cent. of the pitch. The residue from the sodium carbonate solution was then boiled with a dilute solution of sodium hydrate and the dissolved ulmin was precipitated with hydrochloric acid in considerable amount.

The acid solutions were neutralized with sodium hydrate, acidulated with acetic acid and the apocrenic acid precipitated with acetate of copper. Only a trace of crenic acid was precipitated by ammonia. This might reasonably be expected, as crenic acid is being continually converted to apocrenic acid by contact with reducing sub-

stances, of which bitumen is a notable instance. I am inclined to think that Prof. S. W. Johnson's observation, that ulmin represents only the ulmic acid of difficultly decomposable ulmates, is correct ("How Crops Feed," p. 225, note). It is well known that ulmic acid and ulmin have the same composition, but the first is readily soluble in Na_2CO_3, while the latter requires prolonged boiling with NaHO for its solution. I believe that the ulmin represents only the ulmic acid that is in combination with alumina and iron, which compounds are decomposed with considerable difficulty.

Wiley, in his "Principles and Practice of Agricultural Analysis," Vol. I, p. 28, recommends for the determination of humic and ulmic acids the use of the Huston-Grandeau method, as follows: 10 grams of the soil are washed with a 3 per cent. solution of HCl, and then washed into a 500 c.c. cylinder with a 4 per cent. solution of ammonium hydrate. Shake and let remain in a horizontal position for thirty-six hours. Determine the humus in an aliquot part. This is, no doubt, a very good method for ordinary soils containing free peat acids and their salts of lime and magnesia; but, used on No. 8, the amount of ulmic acid obtained was only 0·044 per cent. against 1·542 per cent. obtained by the sodium carbonate method. In parianite the peat acids are, no doubt, combined with iron and alumina, as only traces of lime and magnesia were found in the HCl solution.

The ammonia that has been observed escaping from kettles of melted pitch when it is refined is, without doubt, derived from the amido compounds referred to above. The relation which the pitch bears to a soil is strikingly shown in the luxuriant vegetation that covers the pitch wherever it is not in motion. Outside the lake a tropical jungle grows, with its roots penetrating the pitch and forming a sod of great tenacity, which often renders tons of the pitch worthless from admixture of vegetable matter. Such pitch is universally rejected.

THE DETERMINATION OF WATER.

The pitch is taken from the lake dripping wet. It begins to dry out immediately, but it requires a long time to completely remove the water if the lumps are unbroken. It is, however, easily dried if pulverized and placed in the sun. By thus drying to a constant weight the water may be determined.

Another method that I have found very convenient for determining water in semi-fluid or solid bitumens is to dissolve the bitumen in refined and recently distilled illuminating oil and distil in an alembic or tubulated flask, collecting the distillate in a graduated cylinder and measuring the water, which may be estimated to weigh a gram to a cubic centimeter at 60° F. For this purpose, at least 50 grams of the bitumen should be dissolved in 200 cubic centimeters of the liquid, and the distillation should be continued until no more water passes over.

PETROLEUM ETHER SOLUTION.

For this determination three washed filters should be balanced. Into two of them should be weighed 1 gram of the pitch. These filters should be placed in separatory funnels and exhausted with dry petroleum ether, of 74° B. or higher, as rapidly as possible. The percentage of dry pitch dissolved by the petroleum ether will vary within narrow limits from 32 to 36 per cent.

Of those analyzed by Miss Linton, Nos. 6, 7, 8, 9 and 17 were commercial lake pitch. They contained the following named amounts of petroleum ether solubles:

	Petroleum Ether.	Mineral Matter.	Total Bitumen.		To Mineral Matter.
No. 6	36·650	35·337	1	:	·656
" 7	36·372	35·975	1	:	·671
" 8	36·475	35·712	1	:	·657
" 9	35·950	35·192	1	:	·651
" 17	34·200	35·645	1	:	·672
Average . .	35·929	35·572	1	:	·661

Nos. 21, 22, 23, 24, 25, 26 and 16 were from the annular

space between the tramway and the edge of the lake. They were all specimens of good, clean cheese pitch.

	Petroleum Ether.	Mineral Matter.	Total Bitumen.		To Mineral Matter.
No. 21	26·925	36·537	1	:	·699
" 22	34·725	36·310	1	:	·688
" 23	34·412	35·612	1	:	·672
" 24	33·187	36·175	1	:	·686
" 25	34·900	38·462	1	:	·754
" 26	35·362	38·762	1	:	·774
" 16	35·400	36·100	1	:	·681
Average	33·558	36·851	1	:	·707

Nos. 1, 2, 4, 10 and 14 are samples of clean commercial pitch, from points outside the lake.

	Petroleum Ether.	Mineral Matter.	Total Bitumen.		To Mineral Matter.
No. 1	33·617	37·462	1	:	·737
" 2	33·620	36·201	1	:	·692
" 4	33·736	36·729	1	:	·701
" 10	33·730	35·886	1	:	·682
" 14	31·775	37·460	1	:	·743
Average	33·295	36·747	1	:	·711

Placing the averages together they give:

	Petroleum Ether.	Mineral Matter.	Total Bitumen.		To Mineral Matter.
C. Lake	35·929	35·572	1	:	·661
Annular Lake,	33·558	36·851	1	:	·707
C. Land	33·295	36·747	1	:	·711

Mr. Richardson raises the average in the annular space to 35·2 by throwing out No. 21, which he had no right to do, as No. 21 was a specimen of clean cheese pitch from inside the lake, and some distance beneath the surface. There is no better reason for throwing it out than for throwing out No. 17 from the lake pitches.

The annular space from which the seven specimens above enumerated came represents 80 per cent. of the surface of the lake and probably 70 per cent. of the entire mass. This 70 per cent. is constantly moving towards the center of the lake as the pitch is removed along the tramway.

Taking the specimens on the line of outflow from No. 17 to No. 2, we have:

	Petroleum Ether.	Mineral Matter.
No. 17	34·200	35·645
" 9	35·950	35·192
" 6	36·650	35·337
" 7	36·372	35·975
" 8	36·372	35·712
" 16	35·400	36·100
" 10	33·730	35·886
" 4	33·736	36·729
" 2	33·620	36·201
" 1	33·617	37·462

Showing conclusively that, with slight variations, the mineral matter increases from No. 9 at the center of the lake to the village lots, Nos. 1 and 2, nearest the sea.

The petroleum ether soluble in my five specimens of commercial lake pitch is on an average 1·186 per cent. above that of the twelve lake specimens. The seven specimens that represent 70 per cent. of the mass in the lake are 0·264 per cent. above the five specimens that were all clean commercial land pitch. It will also be observed that the ratio of total bitumen to mineral matter increases in the averages given from 1 : ·661 in the five lake specimens to 1 : ·711 in the five land specimens. Of course, if the mineral matter increases, the other ingredients must diminish. These differences are so slight that really it is very wonderful that a mass of material of such vast magnitude should present such striking uniformity of composition.

So far as it is possible to use Mr. Richardson's results in a similar manner, they show the same inverse proportion between the amount of petroleum ether soluble and mineral matter as the specimens are taken from points removed from the center of the lake.

If the petroleum ether solution be allowed to stand, it deposits a film upon the surface of the containing vessel beneath the liquid. This deposit is not a precipitate. If the vessel is of glass, the entire surface of the glass beneath the liquid is covered with the film, from which the liquid may be cleanly poured. This film readily dissolves in chloroform to a transparent solution. This chloroform solution evaporated to dryness over a water-bath gave 1·884 per cent.

of the pitch, of a brilliant black solid, which, when heated, melted, distilled, intumesced and burned to a very porous light ash that appeared to be alumina. The ash amounted to 41·508 per cent. of the solid mass or 0·0782 per cent. of the pitch.

If the petroleum ether soluble be treated in solution with fuming nitric acid an orange-colored nitro derivative is obtained, from which the petroleum ether may be easily distilled. An examination of these nitro derivatives is a much more promising field for research than the products of distillation, contaminated as they are with the inevitable decomposition products of high temperatures.

THE TURPENTINE SOLUTION.

When in California, in 1894, I treated 100 grams of lake pitch with boiling spirits of turpentine, and upon adding to the solution a large excess of petroleum ether, obtained a copious brown precipitate. I gathered this precipitate on a filter and washed it with petroleum ether, in which it is wholly insoluble. It is also insoluble in ethyl ether and ethyl and methyl alcohol. Heated in a platinum crucible, it yields a large percentage of ash. This ash consisted of:

Silica	—
Alumina	—
Iron	—

For a long time I supposed this precipitate was asphaltene, but on attempting to determine the sulphur in it I found it was an organic compound of silica and alumina. I have not yet completed my investigation of this material, which I believe is a double salt of alumina, containing ulmic acid.

More than 12 per cent. of the precipitate may be dissolved in solution of sodium carbonate and a still larger percentage may be dissolved in solution of sodium hydrate, from both of which solutions hydrochloric acid will precipitate an organic acid. This material also furnishes a much more inviting field for research than the decomposition products of distillation. Dr. Endemann isolated from the residue that he obtained by his peculiar process a substance

that he called asphalt-ulmic acid. It is, no doubt, ulmic acid that had survived the fiery ordeal through which his residue had been made to pass, and was one of the few constituents of the original parianite that had escaped decomposition.

THE CHLOROFORM SOLUBLE.

When the residue left on the filter from treatment with boiling spirits of turpentine is treated with cold chloroform, a third portion is dissolved. The percentage varies with the pitch. In those analyzed by Miss Linton it varied in the five land pitches from 3·139 to 8·185, in the lake pitches from 2·137 to 7·222, and in those from the annular space from 4·800 to 6·990. In the rubbish it varied from 1·300 to 15·112. The average of the

	Per Cent.
Five land pitches	6·504
Five lake pitches	5·012
Seven annular pitches	5·604
Five rubbish	10·334

The two Épureés were 2·675 per cent. and 9·187 per cent. The two refined pitches were 6·002 per cent. and 6·297 per cent.

When the soluble is evaporated from the chloroform it forms a brilliant, black, hard varnish. Heated, the varnish melts, intumesces, gives off heavy vapors which burn with a smoky flame, leaving a red ash, consisting chiefly, if not wholly, of ferric oxide. In one instance a portion of this varnish yielded 0·779 per cent. of this ferruginous ash.

This soluble is precipitated from its solution in benzole or chloroform upon the addition of an excess of petroleum ether, as a seal-brown powder. This precipitate may be washed with petroleum ether, ethyl alcohol or ether, in all of which it is insoluble. Analyses, that have been fully described elsewhere, and for which no claim for absolute accuracy is made, have shown this precipitate to consist of an organic sulpho-salt of iron (*Jour. Soc. Chem. Ind.*, December, 1897, No. 12, Vol. XVI). Here is also a more profitable field for research than is found among the decomposition products of distillation.

THE HYDROCHLORIC ACID SOLUTION.

Whenever limestone forms any part of a bituminous mixture, whether natural or artificial, it is essential that it should be determined. When crushed stone is used, some portion of it is usually soluble in hydrochloric acid. Gypsum is also dissolved by it, and may be detected by testing the solution for sulphuric acid. A very small percentage of the residue of parianite after chloroform is soluble in a 10 per cent. solution of hydrochloric acid. I have not ascertained what elements enter this solution.

THE RESIDUE.

That which remains on the filter after treatment with hydrochloric acid consists of cellulose and humus, mixed with such mineral matter as is not in organic combination in the pitch. The organic matter cannot be burned off without decomposing pyrite and burning out more or less of the sulphur, as the ash of the filter is usually saturated with ferric oxide in the form of colcotha. The proper procedure is to cut the filter in small pieces, mix these pieces with sodium carbonate and potassium nitrate and deflagrate. The silica, iron and alumina can then be determined while the sulphur appears as sulphuric acid, in the usual way. By determining the sulphur in another portion of the pitch in like manner and deducting the sulphur found in the residue from the whole amount of sulphur, the sulphur in organic combination can be ascertained. At the same time that this total amount of sulphur is determined, the total amounts of silica, alumina and iron can also be correctly determined. This correct total amount of mineral matter will be found to be considerably in excess of the amount found by the usual method of analysis by solvents; inasmuch as an appreciable amount of alumina and iron in combination with organic radicals pass into solution, which exist in the pitch dissolved in the bitumen, and which in the process of analysis pass into the solutions formed by the various solvents employed.

In the remarks made by Mr. Clifford Richardson, at the

time the paper was read, of which myself and my son were joint authors (*Jour. Soc. Chem. Ind.*, May 31, 1897), he was made to observe (I quote from memory) "that the percentages given were percentages of the ash. Adding together the 19 and 21 made 32. The silica and oxide of iron made up the total." In this he was mistaken. The percentages given, 19·182 per cent. and 21·168, amount to 40·350. In the ordinary method of analysis by solvents, with combustion of "organic matter not bitumen" and determination of the residue from the combustion, the organic matter not bitumen amounted to 8·507 per cent. and the mineral matter to 32·243 per cent. How large a part of the organic matter not bitumen was sulphur cannot be conjectured; but no question can be entertained for a moment that a very considerable portion of the 3·639 per cent. of sulphur is lost in that way. Whatever the amount may be, the total per cent. of material that is not bitumen, obtained by solution, is 40·750, while the sulphur, silica, alumina and iron, by the direct method amounts to 43·989 per cent. 19 and 21 make 40, instead of 32, as Mr. Richardson suggested.

In the paper lately published by Mr. Richardson (*Jour. Soc. Chem. Ind.*, January 31, 1898), and which I have elsewhere noticed (*Jour. Soc. Chem. Ind.*, November 30, 1898, p. 1003), he draws some very extraordinary conclusions, which he states as follows: "The additional determinations of bitumen made by Professor Peckham with chloroform also furnished some additional and conclusive evidence of the difference between the two kinds of material (pitch from within and without the lake). These show that the average land specimen contains 2·4 per cent. more of its bitumen in this difficultly soluble form, while iron pitch, which is acknowledged to be of no value for paving purposes and is always rejected in digging land pitch, has 7·3 per cent. more of its bitumen in this form. From this we can draw the inference that the land pitch collected by Professor Peckham is one-third converted into iron pitch, and of so much less value than lake pitch for paving purposes. In fact, his results are conclusive evidence of the differences between lake and land pitch as any that have been offered, and con-

firm the result of experience with the asphalt from the land deposit in the laying of street pavements."

This remarkable paragraph, in the first place, is incorrect in its arithmetic; in the second place, in assuming any relation between commercial pitch, either lake or land, and iron pitch, hence in assuming that any ratio exists between lake and iron pitch. Using Mr. Richardson's figures, the chloroform soluble of the average lake specimens is 9·848 per cent. of the total bitumen in those specimens. In the land specimens the chloroform soluble is 12·572 per cent. of the total bitumen. In the single iron pitch selected by him (3) the chloroform soluble is 17·308 per cent. of the total bitumen. The differences are 2·724 and 7·460 per cent. The average chloroform soluble in the five commercial lake specimens, 6, 7, 8, 9 and 17, correctly determined, is 9·331 per cent. of the total bitumen. In the seven specimens in the annular space between the tramway and the circumference of the lake, Nos. 21, 22, 23, 24, 25, 26 and 16, the chloroform soluble averages 10·771 per cent. of the total bitumen. In the five commercial land pitches, Nos. 1, 2, 4, 10 and 14, the chloroform soluble averages 12·569 per cent. The chloroform soluble in the iron pitches, Nos. 3 and 18, averages 22·709 per cent. of the total bitumen. Arranged in order with differences according to Mr. Richardson's argument, they are:

Lake	9·331		
Annular	10·771	difference	1·440
Land	12·569	"	3·238
Iron	22·709	"	13·378

According to Mr. Richardson's argument, the pitch in the annular space is one-sixth converted into iron pitch and the land pitch is one-fourth converted into iron pitch. Keeping on with the argument, the lowest ratio of chloroform soluble to total bitumen in any of the specimens examined by Miss Linton is in No. 8. In this specimen the chloroform soluble is 3·932 per cent. of the total bitumen. This specimen came from outside the tramway. In No. 9, from the center of the lake, the chloroform soluble is 10·668;

that is, the pitch at the center of the lake is nearly three times nearer iron pitch than that outside the tramway. In No. 17, just outside the tramway on the southwest side, the chloroform soluble is 13·648, or four times nearer iron pitch than No. 8 on the northeast side. Or, according to this argument, assuming, as we have a right to, that pure pitch has no chloroform soluble, that the pitch at the center of the lake is one-half converted into iron pitch. The fact of the case is, however, that iron pitch is not a decomposition product, nor is the chloroform soluble an effect of decomposition, although the accumulation of this ingredient of the pitch in large amount may apparently result from the decomposition and partial removal of the other constituents. Nos. 11 and 13 are so-called "chocolate pitch." The material is plainly the result of a sort of partial decay of the pitch. The average percentage of petroleum ether soluble in these two specimens is only 38·980 per cent. of the total bitumen, while the chloroform soluble is 26·824 per cent. of the same. Chocolate pitch is found in very small quantity in the deposit wherever the conditions are favorable to its production, but it is not a commercial product. Iron pitch has been formed by the melting and partial distillation of the pitch from jungle fires, and is so uniformly rejected from the commercial pitch that it is almost impossible to find a piece of appreciable size in a cargo of crude pitch.

THE ORGANIC MATTER NOT BITUMEN.

In the seventeen specimens of crude pitch, taken from as many different points, both within and without the lake, the so-called organic matter not bitumen was found to be on an average 11·074 per cent. of the pitch. Precisely of what this consists has not been determined. It is obtained by burning the residue that remains from the solution in chloroform, at a dull red heat. If the pitch is not finely pulverized, but is treated in coarse lumps, the residue from the chloroform contains fragments of vegetation of appreciable size. There is also a considerable amount of an exceedingly fine gray powder that is easily recognized as

ferrous sulphide. A determination of the sulphur in this residue gave 0·8844 per cent. of the pitch; this is equivalent to 9·793 per cent. of the residue, or, 18·368 per cent. of the residue of ferrous sulphide. These figures are suggestive rather than final.

THE MINERAL MATTER.

This is the residue left in the crucible after the organic matter not bitumen has been burned off. It consists of grains of silica with a small amount of alumina and a much larger proportion of ferric oxide in the form of colcotha, which indicates that it is a product of decomposition, and that, too, of a substance that is very intimately mingled with the entire mass of the residue and even the fiber of the paper. The paper is as completely filled with anhydrous ferric oxide as if it had been previously soaked in a saturated solution of ferrous sulphate.

The average totals of this mineral matter in the seventeen specimens of normal crude pitch is 36·444 per cent. If, however, the mineral matter, that is, the silica, alumina and sulphur, are directly determined, they will amount to:

	Per Cent.
Silica	19·593
Iron and alumina	20·272
Sulphur	3·505
Total	43·370
By solution	36·444
Difference	6·926

This difference of nearly 7 per cent. is certainly represented by constituents of the pitch, a part of which pass into solution in the solvents of the pitch and a part of which are volatilized as "organic matter not bitumen."

I am satisfied to frankly admit that at present we know very little concerning the composition of parianite, and further, to state my belief that nothing of any material value will be added to our present scant information until it is investigated rationally instead of empirically. This is a work of a lifetime.

ANN ARBOR, MICH., June 1, 1898.

Discussion.

Dr. H. Endemann:—I shall confine my remarks mainly to the methods of analyzing asphalts. There are at present two methods in use:

(1) Examination of asphalt by the successive use of solvents.

(2) The analysis of asphalt based upon the volatility of some constituents and the determination of the elementary composition of the non-volatile portion.

Prof. S. F. Peckham, following the lead of C. Richardson, is the representative of the first method, while I have devised the latter.

In my papers on asphalt, published in the *Journal of the Society of Chemical Industry*, during the years 1897 to 1899, I have shown, by qualitative tests and quantitative determinations, that the analysis of asphalt attained by the successive use of solvents is not an analysis at all, according to the standpoint of the chemist.

To divide a mixture into fractions each of which contains all the elements of the original mixture is not an analysis.

My results show that the fractions obtained by this method of examination are mixtures of all the constituents in asphalt in varying proportions.

The fraction obtained with petroleum ether contains the bulk of the volatile and stable hydrocarbons, but it contains twice as much of non-volatile hydrocarbons and organic substance containing oxygen. The residue is the same, only that it contains less of the volatile hydrocarbons. If this residue is treated, as proposed, by spirits of turpentine, this solvent will remove the last of the volatile hydrocarbons, together with a corresponding quantity of the non-volatile portion. The proportion of the latter which goes into solution depends entirely upon the amount of the volatile portion left in the residue from the first treatment. If no volatile hydrocarbons have been removed from an asphalt, the whole of the bitumen is soluble in spirits of turpentine.

The following is a short history of asphalt analysis.

The first to investigate asphaltum was Boussingault. He made an elementary analysis of the asphalt of Pechelberon and found that it contained aside of carbon, hydrogen, sulphur and nitrogen, about 2½ per cent. of oxygen. He then subjected it to distillation, when he obtained an oil of the approximate composition $C_{16}H_{16}$, and a very much larger quantity of a solid residue containing 15 per cent. of oxygen. The oil, which is really a mixture of hydrocarbons, he called petrolene and the latter asphaltene. That the latter product must be a product of a process of oxidation is evident. Say that he obtained 60 per cent. of asphaltene with 15 per cent. oxygen, the original asphalt should have contained 9 per cent. of oxygen in the place of 2½ found. This proves the process of oxidation without doubt.

Boussingault did not pursue the subject.

At the meeting of the American Chemical Society, held in Washington during the summer of 1892, C. Richardson read a paper on "Trinidad Asphalt," where he first introduced the method of examination by successive use of solvents, and introduced it as a simplification of the discredited Boussingault method, claiming that the petroleum ether extract was practically the same as the petrolene of Boussingault; hence he called this extract petrolene. It occurred to me, then, that Richardson's claim that the analysis was a simplification of Boussingault's, and practically alike in effect, was at least very doubtful. I did at that time not discuss his paper for the reason that I desired confirmation of my suspicions by practical experiment.

Whether he really tried to identify the petroleum ether extract with Boussingault's petrolene is doubtful. Certain it is that he used the name petrolene for his petroleum ether extract, and it is likewise certain that if he had earnestly tried to compare the two, he should have observed that only one-third of the petroleum ether extract consists of volatile hydrocarbons or Boussingault's petrolene, while two-thirds are fixed bodies.

Of reasons which caused me to look with suspicion upon the new method, I mentioned, for instance, logwood extract.

The poorer brands of the liquid extract are perfectly clear syrupy liquors, which, when dropped into water, separate into a water-soluble part and a muddy precipitate. The latter, when brought upon filter, is found to be insoluble in water.

But asphalt is a similar substance. I have in this bottle a solution of asphalt in petroleum ether, and in the second bottle pure petroleum ether, same as was used for the preparation of the extract. I now pour some of the solution into petroleum ether, and you can now see already that the solution becomes turbid, and at the end of the hour you will observe a precipitate covering the bottom of this four-ounce bottle with a layer of precipitate about $\frac{1}{10}$ inch in thickness.

These examples show that the solubility of one substance in another is, to a great extent, governed by the presence of a third substance and the concentration.

Prudence prescribes that in preparing a method the possibilities of such interference are considered and determined.

In the case of this method these precautions have been neglected entirely.

The reasons that I had not accepted the method by solvents are based upon the following experiments:

I took the petroleum ether extract left after the evaporation of the petroleum ether and heated it for a short time to a temperature near the one used in refining. I found that I could drive off in two hours one-third of its weight. The residue, or two-thirds of the extract, was a solid, but could then again be divided in a petroleum ether soluble and insoluble fraction.

There was in this process no actual distillation,but simply evaporation much below the boiling point of the volatilized substances. There was no flame, smoke or ashes in this process, as Mr. Peckham desires to imply.

As further steps I ascertained that, if this evaporation in air is prolonged, it is accompanied by dehydrogenation and oxidation by addition of oxygen, and also that such changes may be obviated if the evaporation of the stable volatile hydrocarbons is effected in a current of an inert gas,

for which I selected, for convenience, carbon dioxide. These points were elicited by a series of elementary analyses.

The line of investigation partly outlined here and followed up step by step landed me on the following facts:

Asphalt consists:

(1) Of a solid body, non-volatile, or, if volatile, at a very high temperature only, which forms the body of the asphalt and is the predominant constituent.

This solid body is in some asphalts a hydrocarbon, with less hydrogen than any of the petrolene hydrocarbons. Its composition corresponds to the formula $C_{26}H_{38}$. Isomers of this I have so far not found. It has been found in liquid asphalts.

Higher oxidized and hard asphalts may contain this, but they are characterized by the presence of an oxygen compound or oxygen compounds.

My first investigations led me to a formula $C_{26}H_{36}O_2$, but lately, with new asphalts, I have been led to a formula $C_{20}H_{24}O_2$. The first contains 8·5 per cent. oxygen; the latter, 10·5 per cent. oxygen; both oxidize alike when heated in a current of air to about 200°–250° C., the first yielding a compound with 15½ per cent. oxygen; the latter, one with 23 per cent. oxygen. (Asphaltic acid or oxide.)

Other homologues I have so far not found.

(2) Volatile hydrocarbons, mostly liquid, which are present in smaller quantity and which have been called "petrolenes."

The substances under 1 are solids which are softened by those under 2 in the same way as 80 rosin and 20 spirits of turpentine make 100 turpentine.

I have further shown that asphaltic acids dissolve in caustic soda under absorption of oxygen, forming asphaltulmic acid. It is not in asphalt, or certainly is not contained in the bitumen; it was simply prepared by me in the hope of settling the nature of the products from which it is derived. I also desire to say that in my opinion the ulmic acid obtained by Peckham from Trinidad pitch by the process described in his paper is derived from the spirits of turpentine used in its preparation, for spirits of turpentine

almost always give a precipitate on addition of petroleum ether, which precipitate is, after drying, soluble in carbonate of soda. I have ascertained that the residue left from the petroleum ether extract or the whole of the bitumen without intervention of spirits of turpentine do not give anything to soda, except, perhaps, invisible traces.

Asphalts invariably contain some sulphur and nitrogen, and while I was in the belief that these all pass off with the petrolenes, I found them later on in all products if they once were incorporated.

In many asphalts sulphur may be almost entirely removed by washing with water. If such asphalts, however, are refined, *i. e.*, heated to a considerable degree before washing, the bitumen will contain sulphur, and this sulphur will pass through the whole series of products. In what form this sulphur exists I am not prepared to say, nor do I know in which form the nitrogen exists, except that I have so far not been able to extract from asphalt nitrogenous basic substances.

Sulphur does not act in asphalt, as Lefkowitch, of London, says, when he suggests that it plays the same role in asphalt as in the vulcanization of rubber. It would be interesting to hear on what data his belief is founded.

I have shown, also, that the belief of others is not well founded in this respect. So-called analyses which were made to prove the fact and likewise deny my assertion of the presence of oxygen in some asphalts I have shown to be unreliable.

For instance, Richardson, in the *Journal of the Soc. of Chem. Industry*, 1898, p. 20, shows how he calculates the composition of the organic substances in asphalt in the following manner :

	As Obtained.	Organic Matter.
Carbon	10·60	52·65
Hydrogen	1·55	7·69
Sulphur	2·08	10·32
Nitrogen	0·42	2·05
Mineral matter (ashes)	79·85	—
Oxygen by difference	5·50	27·29

It is certainly quite original with him, but I am inclined to think that his lead will not be followed.

Sulphur is, in my opinion, in asphalt for the reason that sulphates have passed their oxygen for the oxidation of organic matter. It is not the determining substance, but an incident, a residue from a chemical reaction, the same as we look upon sulphates as the sources of pyrites in bituminous coal or other carboniferous minerals.

In order to show that it is the oxygen mainly which produces the bitumen, I have undertaken to prepare asphalt from petroleum under conditions which prevent sulphur from acting on the organic material.

The material used by me were heavy lubricating oils from the Standard Oil Company. 100 grams of this were treated with a solution of 300 grams bichromate of potash, 600 grams sulphuric acid, 2 liters of water.

The mixture is frequently agitated and kept upon the water-bath for from 2–4 months. The oil gradually thickens and takes the characteristic odor of asphalt. An examination of the products led me for the first time to an asphaltic acid with 23 per cent. of oxygen.

It is only quite recently that this product was obtained by me from some Western natural asphalts (Kentucky).

A good deal has been said about the peculiarity of asphalt solutions containing mineral matters. All explanations made so far are surmises due to a desire to explain the phenomenon on the basis of other well-known facts. Work to explain it has not been done, partially, perhaps, for the reason that the really bituminous portion of asphalt is the subject of greatest interest. The precipitate which I produced in the petroleum ether solution by the addition of more petroleum ether contains generally about 10–12 per cent. sulphur and much mineral matter.

My method of analysis consists:

(1) Extraction of all bitumen by chloroform.

(2) Evaporation of volatile hydrocarbons in a current of carbon dioxide from the extract.

(3) Direct determination of carbon, hydrogen, sulphur and nitrogen and calculating oxygen by difference.

(4) Determination of asphaltic acid as a check.

In answer to question of Professor Day, I would state that

I anticipate that the use of steam in the place of carbonic acid for the purpose of evaporating the petrolenes will be a good equivalent. I have used carbonic acid for convenience.

I never used nitrogen.

In answer to inquiry, I would state that I determine nitrogen by Kjeldahl method.

For the determination of sulphur I treat the asphalt in a capacious platinum crucible with fuming nitric acid. The asphalt, though still liquid when hot, is comparatively brittle when cold, and can then be mixed most intimately with nitre and soda. After drying in the air-bath I deflagrate and then proceed as usual.

In answer to the remark of Professor Sadtler that asphalt is changed during the process of refining, I would state that I agree with him. The cause of such changes is the presence of the non-bituminous impurities in asphalt, partly pertaining to the mineral matter.

Extracted and purified bitumen is quite stable under the influence of temperatures used in refining asphalts. These temperatures can, therefore, be safely applied in analysis.

DR. S. P. SADTLER stated that he was ready to admit the complexity of constitution of Parianite or Trinidad pitch as maintained by Professor Peckham, in that it probably contained some of the mineral bases in an organic combination whether we concede that the organic substance is really humic acid or not; that it was, moreover, so unstable that it could not be heated directly without some decomposition. However, he did not think that this complexity applied to all natural bitumens—he recalled the natural bitumen of Uvalde County, Tex., which could be extracted from the limestone rock, in which it occurred naturally, by the use of a naphtha solvent; that the same was true of the natural bitumen of Santa Barbara County, Cal., where the Sisquoc asphalt was extracted in that way; that he had analyzed a natural bitumen from Joplin, Mo., occurring in the cavities in the zinc-bearing rocks, which was also almost entirely soluble without residue in petroleum naphtha. With reference to Dr. Peckham's method of analysis of

bitumens, he was not satisfied that turpentine was to be depended upon as a desirable solvent. It was obvious that freshly-rectified spirits of turpentine, and that which had been exposed to the air for a time as warm turpentine upon a filter and had in consequence become somewhat resinous, would have distinctly different solvent powers. He had had occasion, in connection with another matter, to test this difference between turpentine free from resin and turpentine carrying resinified products, and knew that it affected the solvent action notably. To use turpentine, therefore, one would have to note its optical constants so as to insure its entire uniformity.

Dr. Sadtler stated that he had at one time proposed acetone as a solvent in asphalt analyses in place of petroleum ether, because it could be had of fixed boiling point and perfect purity, but found that its solvent power varied from that of petroleum naphtha, and therefore no longer tried to use it as a substitute. What is wanted is a study of the action of a series of solvents of fixed purity upon different natural bitumens.

DR. WM. C. DAY:—It seems to me that Professor Peckham's method of analysis of asphalts is capable of yielding valuable results, particularly when applied to Trinidad asphalt, which is in a number of respects unique. The paper indicates that the alumina found in the mineral matter of the asphalt is present not as a constituent of clay, but as a base in salts of organic acids. This result is certainly interesting, and by itself would justify the entire investigation and the proposal of this method of analysis. I, for one, would be glad to see the method extended in its application. I should think, however, that the directions for carrying out the various separations should be as exact and specific as possible, since some of the solvents used are more or less variable in their chemical constitution and also in their solvent action, according to the temperature at which they are applied.

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The need for uniformity in the method of analysis of asphalts is very great; this applies to elementary analysis

as well as to the analytical separation of compounds and groups or classes of compounds. I hold in my hand an interesting paper, by Mr. Clifford Richardson, with which I have no doubt you are all familiar. A table of elementary analysis of asphalts is given, in which oxygen is not mentioned as a constituent element. His results in the case of Utah gilsonite differ so markedly from a number that I have obtained with the same substance, that I am at a loss to account for the discrepancies. He finds nitrogen in Utah gilsonite 0·79 per cent., while in ten different determinations by the Gunning modification of the Kjeldahl method I find an average of 2·40 per cent., with extremes of 2·25 and 2·52, generally nearer the latter figure. I think if those who are investigating asphalts could get together and agree on uniform methods of analysis and calculation of results, the cause of asphalt investigation might be benefited.

Dr. H. F. Keller made some comments in the discussion, referring more particularly to the remarks of Dr. Day and Dr. Endemann. After the former's reference to the disagreement of the nitrogen determinations in various asphalts, and the manner in which they had been made, Dr. Keller suggested that more concordant results and certainly more reliable figures might be obtained by combustion of the material with copper oxide than is possible with the Kjeldahl method.

With reference to Dr. Endemann's statement that the treatment of asphalts with solvents could not be regarded as an analysis, Dr. Keller called attention to the fact that his method does not permit the separation of individual compounds any more than the use of solvents. To Dr. Keller's question whether he (Dr. Endemann) had made any attempt to isolate any compounds of definite composition he replied negatively.

Mr. Alfred H. Allen, Sheffield, England [Correspondence]:—I am duly in receipt of your letter of the 8th instant, accompanying the advance copy of Professor Peckham's paper on Parianite, for which I am obliged.

I have read the paper carefully, and am glad that the difficult subject of the constitution of asphalt continues to

receive the enlightened attention of Professor Peckham. I think every one must agree that much remains to be done in the way of isolating the proximate constituents of asphalt, and the non-crystalline character of the products renders their isolation in a state of purity a matter of peculiar difficulty.

I quite approve of Professor Peckham's remark that an examination of the nitro-derivatives of the various fractions isolated by the action of solvents affords a promising field for research. I would go further than this, and suggest the investigation of the bodies produced by the action of bromine, preferably in solution in carbon tetrachloride.

It has been frequently observed that the crystallization of organic bodies has prevented the presence of very small proportions of impurities. I do not know whether any attempt has been made to purify the various fractions obtained by the action of neutral solvents. If not, I would suggest that the solutions of these fractions should be agitated with weak acid and alkali with the view of removing traces of substances of alkaline and acid character. It would also be interesting to know how far nitrogen, oxygen and sulphur enter into the composition of any of the fractions obtained by Professor Peckham and Miss Linton; in fact, I am rather struck by the absence of any elementary analyses of the products obtained.

It is evident that plenty of work remains to be done on this interesting but difficult subject, and I shall watch with interest the further progress made by Professor Peckham and his able collaboratrix.

PROF. PECKHAM:—The use of spirits of turpentine was first suggested by the directions given in the first edition of Allen's "Commercial Organic Analysis." It is directed there that the bitumen in European asphaltic rock be dissolved from the mineral matter in freshly distilled Russian turpentine. The turpentine should be freshly and doubly distilled. In any case the filter should not be digested in turpentine, which, poured upon the filter while hot, has been allowed to get cold. The stopcock in the funnel should be closed, the filter filled with boiling turpentine, the stopcock imme-

diately opened and the hot turpentine allowed to run off as rapidly as possible. This should be repeated until the turpentine is discharged colorless. There are very great differences observed in the action of boiling turpentine upon asphaltums and bituminous minerals from different localities. In some cases the solution is as readily affected as sugar and water; in other cases the solution takes place much more slowly. The points made by Drs. Endemann and Sadtler are theoretical, not practical; any other solvent, as, for instance, any of the benzole series that will dissolve the material not soluble in petroleum ether, will yield this precipitate on dilution with a large excess of petroleum ether. I have digested this precipitate in dilute hydrochloric acid, then in a dilute solution of sodium hydrate, which became highly colored, and then obtained a copious precipitate of an organic acid, in brown flocks, when the sodium hydrate solution was acidulated.

It is true that on the large scale the bitumen of the Uvalde County bituminous limestone has been extracted with petroleum naphtha, yet I have never found among the many samples of this rock that I have tested a single sample in which the bitumen was all soluble in petroleum ether. It is, however, practically, all soluble in boiling turpentine. On the large scale, the portion insoluble in petroleum ether is washed out of the rock by the solution of the remainder in the petroleum naphtha, and the purified bitumen consists of a mixture of the two solubles.

I have for some time been of the same opinion, so well expressed by Dr. Sadtler, that "What is wanted is a study of the action of a series of solvents of fixed purity, etc." I have in hand the material for precisely this work, but have hitherto been unable to devote to it the necessary time.

I also recognize the force of Mr. Allen's remark concerning the absence of elementary analyses. The reason is that hitherto I have not been able to obtain the substances described in this paper under such conditions and in such quantity as to make ultimate analyses advisable. Ultimate analysis should follow the study of the action of solvents of fixed purity. I have for some time been planning the

use of one of the pure paraffines, of low boiling-point, the solution obtained being fractionated in vacuo and treated as if it were a crude petroleum or naphtha. The action of pure alcohols, both absolute and of definite dilution, as well as of the benzole series in pure forms, is to be studied both separately and in series. There is work enough on these problems to fill the twentieth century.

Stated Meeting, held Tuesday, April 18, 1899.

ON SERIES IN SPECTRA.

BY DR. EDWARD A. PARTRIDGE.
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The investigation of relations between the spectra of different elements has been a favorite subject of inquiry ever since spectra have been studied. No one can attentively examine drawings of the spectra of a series of related elements without being impressed with their general similarity.

Lecoq de Boisbaudran* was the first to give a detailed description of this similarity. He did this in a number of articles in the *Comptes Rendus* of 1869. In 1886† he published a method by means of which he calculated the atomic weight of germanium from its spectrum. He writes as if he had known the law for a long time, but I can find no evidence of it having been published before 1886. His statement of the law is as follows:

"In the natural families of elements the variation in the increment of the atomic weight is proportion to the variation in the increment of the wave length of homologous rays or groups of rays in the third harmonic of the spectrum."

Ames‡ examined this statement critically, and found

* *C. R.*, t. 69, pp. 445, 606, 694, 1869.
† *C. R.*, t. 102, p. 1291, 1886.
‡ *Phil. Mag.*, 30, 33, 1890.

that it cannot be considered general, although it may apply roughly to certain groups of lines.

One difficulty is to pick out those lines which are to be considered homologous. This is not an easy matter in complicated spectra.

The recognition of the fact that the spectrum of an element depends upon the structure of the molecule and atom of the element gave hopes of learning something of that structure.

Light, being a periodic phenomenon, calls up visions of a vibrating system causing the light.

Here, then, is the problem: from the spectrum of an element to calculate the structure of its molecule and atom. The cognate problem in sound would be: from the combination of tones emitted by a bell to calculate its size and form, the density and elasticity of the material of which it is made.

The acoustical analogy has, however, hindered rather than helped progress in that direction, for it encouraged investigators to seek for simple harmonic relations between the frequencies of the vibrations given out by a molecule. Harmonic relations are to be understood as meaning whole number ratios, such as exist between the fundamental and overtones of an organ pipe or a piano string. This point has been emphasized, since the term harmonic has been frequently used to indicate simply a relation, no matter what the law of the relation might be.

The idea of harmonic relations existing between the frequencies corresponding to the several lines of a spectrum existed as a part of common knowledge among spectroscopists for a long time. Lecoq, Soret, Stoney and Liveing and Dewar sought such relations. We remember reading in the popular literature of ten or fifteen years ago that the three prominent lines in the visible H spectrum are related as C, F and A of the musical scale are related. Stoney* announced, in 1871, that the frequencies of $H\alpha$, $H\beta$ and $H\delta$ are to each other as 20 : 27 : 32. Similar relations

* *Phil. Mag.*, 41, 291, 1871.

have been announced for other series in other spectra. But all the harmonics are never present, and several fundamentals have to be supposed in order to include a considerable number of lines in the scheme.

With greater refinement of measurement these relations were seen to be only extremely rough approximations. In order to test the question finally, Shuster,* in 1881, proposed the following problem: "Is the number of whole number ratios between the wave numbers greater than would exist if the lines were distributed at random?"

By the calculus of probabilities he found the number of approximate whole number ratios that is to be expected with lines distributed at random. He included in his calculation of whole number ratios all numbers under 100, and the degree of approximation to the exact ratio, in order that it might be called a whole number ratio, was that it should fall within the limits of error of observation at that time. He applied his results to the spectra of *Mg*, *Na*, *Cu*, *Ba*, and in particular to *Fe*, and calculated 10,000 ratios of frequencies. But the number of whole number ratios was less than would be expected on a chance distribution. Now that this question could be regarded as settled, attention was turned to other relations which had long been suspected, but which could not be established in consequence of insufficient refinement in the measurements.

In 1869 Mascart† called attention to the fact that the well-known doublet, the *D* line of *Na*, was repeated six times in the spectrum of that element, and he also stated that the distance between each pair was approximately the same. Later, he noted that the "*b*" triplet of *Mg* is repeated three times in the ultra violet.

In 1871 Liveing and Dewar observed the *Na* doublets, but stated that the distances between the lines of the doublets follow no law. In 1882‡ Shuster said that the differences between the corresponding lines in the triplets

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* *Proc. Roy. Soc.*, 31, 337, 1881.

† *C. R.*, 69, 337, 1869.

‡ *Brit. Ass'n Report*, 1882, 120.

of *Mg* were not regular. In 1883,* however, Hartley proved that these distances are the same; that is, naming the lines in a triplet *a*, *b* and *c*, the distances *a b* and *b c* in one triplet are the same as the corresponding distances in all the triplets. But *a b* is in general different from *b c*. This law he proved for the triplets of *Mg*, *Zn* and *Cd*. I must next describe some work in another field of spectroscopy.

The discovery by Huggins,† in 1876, of the *H* series in the ultra-violet spectra of the white stars exerted a powerful influence in the direction in which much progress has been made. In the *Philosophical Transactions* for 1880 he published an account of his work on this subject. Appended to this article is a note by Stoney, who showed by drawings that there was a high degree of probability that the newly-discovered lines were due to *H*. Cornu‡ afterwards, taking great care in the preparation of pure *H*, proved that the new series was due to that element.

Liveing and Dewar,§ and Cornu noticed series in the spectra of other elements, which resembled the *H* series, and in 1885 Cornu‖ established a relation between the series of *Tl*, *Al* and *H*.

Cornu's relation turns out to be only a rough approximation; it is that

$$\lambda_{\rm Al} = A + b\,\lambda_{\rm H}.$$

Cornu picked out for consideration the easily reversible lines in the spectrum. He tells how he had endeavored, without avail, to find a formula which should express the relation between the lines in the spectrum of an element, and concludes that the quickest way of arriving at the law would be to follow Kepler's example, and try hypothesis after hypothesis in the hope of ultimately achieving success. On account of its simplicity and importance in stellar spectroscopy the *H* spectrum has always attracted a large share

* *Jour. Chem. Soc.*, 43, 390; 1883.
† *Phil. Trans.*, 672, 1880.
‡ *C. R.*, t. 100, p. 1181; 1885.
§ *Proc. Roy. Soc.*, 29, 30, 1880; *Phil. Trans.*, 31, 1881.
‖ *C. R.*, 100, 1181, 1885.

of attention. In 1885, the same year in which Cornu recounted his unsuccessful attempts at finding a law, Balmer,* of Zurich, published a formula by which the wave lengths of the H lines are expressed as simple functions of the integars 3, 4, 5, 6, etc. The formula was originally calculated to express the wave lengths of the H lines in the visible spectrum, but was found to apply as well to the lines discovered by Huggins, in the white stars. The formula is

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 4}$$

λ_0 is a constant, and the whole numbers 3 and following are to be substituted for m.

This formula shows as well as Stoney's drawings that the lines asymptotically approach the limit λ_0, which is the value of λ for $m = \infty$.

The accuracy of this formula is surprising, as it gives the wave lengths to a high degree of approximation. In 1888 Kaiser and Runge communicated to the British Association the fact that they had found a formula, of which Balmer's is a special case, which applied to the series of lines in other spectra.

These were the series to which Liveing and Dewar and Cornu had previously called attention as analogous to the H series. Kaiser and Runge found that the measurements of wave lengths that had previously been made were not sufficiently accurate for their purpose.

They say: "We saw that we were compelled to disregard all the numerical material at hand, and we concluded to determine the spectra of the elements from one end to the other." They first of all measured the spectrum of iron with the utmost care, in order that they might use it as a standard. They tabulated the wave lengths of 4,500 lines in this spectrum. Next, the carbon spectrum had to be studied in order to decide what lines were due to the carbon in the arc and what were due to the element under examination. This done, they began the investigation of the spectra of the alkali metals.

* *Wied. Ann.*, 25, 18, 1885.

The following account of their work is taken from their papers in the *Abhandlungen der Akademie der Wissenschaften zu Berlin*, 1888–1893. An important result of their work was to disprove the statement of Lockyer that there are coincidences between the lines in the spectra of different elements. Such coincidences they never observed. From these supposed coincidences Lockyer drew the conclusion that at the temperature at which he worked the elements were dissociated, and that the common lines were due to common ingredients. No coincidences have been observed by Kaiser and Runge.

From even a cursory examination of their results the great similarity between the spectra of the alkali metals becomes apparent. According to increasing atomic weight, the alkali metals form the following series: *Li*, *Na*, *K*, *Rb*, *Cs*; this is also the series showing the relative ease with which the lines appear.

Li and *Na* appear everywhere, and it is very difficult to obtain the spectrum of *Cs*. Liveing and Dewar had found series in *Li*, *Na*, *K*. Kaiser and Runge found similar series in the spectra of *Rb* and *Cs*.

The general property of these series is that, with increasing atomic weight, homologous series are displaced toward the red end of the spectrum. These experimenters also found that the lines which form series in the spectra of the alkali metals, except *Li*, are doublets. Michelson has completed the analogy in this respect, by showing with his interferential refractometer that the red *Li* line and the red *H* line are extremely close doublets.

But the numerical relations are of much greater interest and importance than these simple analogies. Balmer's formula for the wave lengths of the *H* lines when inverted to give the wave numbers becomes $f = b - 4\,b\,n^{-2}$. This suggested to Kaiser and Runge to try the formulæ

$$f = H + Bn^{-1} + Cn^{-2}$$

and

$$f = A + Bn^{-2} + Cn^{-4}$$

Observation shows that as n increases, the frequency asymptotically approaches the limit A and that the succes-

sive lines approach each other more and more. Trial shows that with proper choice of constants the formula represents the successive lines in the series with great accuracy. This result Kaiser and Runge communicated to the British Association in 1888. They admit that the objection might be raised that an arbitrary formula with three disposable constants could represent with sufficient accuracy a series consisting of say, eight lines.

Having raised this question, they reply to it by means of an example; they apply the formula

$$a + bn^{-1} + cn^{-2} + dn^{-3}$$

containing four constants to the frequencies of the lines of the violet K series. They determine the constants so as to represent the first, third, fifth and seventh lines accurately, and then calculate the second line. The error is sixty times as great as with their three constant formula.

By use of their formula Kaiser and Runge calculated the position of Na lines that had not been observed, and later found them by careful examination of their plates. They found three series of doublets in the spectra of the alkali metals, except Rb and Cs, which have but two series. These series are distinguished by their appearance. They name them the principal series and the first and second subordinate series. The principal series contains the strongest lines of the element, and in all but Li this series is observed to consist of doublets, which become closer and closer as the wave number increases, the difference between the wave numbers of the components of the doublets being about inversely proportional to the fourth power of the number of the doublet in the series.

The number three is the least number for which the formulæ have positive values, hence three is the number corresponding to the least refrangible line in the series. This line is to be regarded as the fundamental line and it was actually observed by Kaiser and Runge in 1890 in the spectra of all the alkali metals, except Cs, where, on account of the high atomic weight, it is in the ultra-red.

In 1892 an elaborate investigation was carried out by

Snow* by the bolometric method, with the object of testing the formula of Kaiser and Runge. He sought and found the infra-red lines of *Cs* very close to the place predicted by the empirical formula, thus furnishing a remarkable confirmation of its accuracy and illustrating its importance.

The lines in the principal series which correspond to the number 4 are in the ultra-violet, so that only the first member of the principal series is visible. The subordinate series lie in the visible part of the spectrum. The first subordinate series is diffuse and reversible, the second subordinate series diffuse on one side and not reversible. These series consist, except in the case of *Li* (due to insufficient dispersion), of doublets which are a constant distance apart in the spectrum of any element. It has been possible to arrange all the lines of *Li* and *Ka* in these series. In the cases of *Na* and *Rb* one doublet remains to be assigned to a place. About the same time that these researches of Kaiser and Runge on the alkali metals appeared, the Swedish Academy of Sciences published an important and elaborate paper which had been presented in 1889 by Rydberg.† The law of constant differences discovered by Hartley, and the series that had been discovered by Liveing and Dewar, formed Rydberg's point of departure. He first of all picked out the doublets and triplets in spectra and separated them into series according to the indications of Liveing and Dewar, who had recognized the nebulous and sharp series. Then he constructed a curve for each series; these curves are similar to that used by Stoney in 1880 to identify the lines discovered by Huggins in the white stars as *H* lines. The form of the curves shows at once that there are asymptotes parallel to the axes, and hence recalls the equilateral hyperbola. Rydberg then, by a careful induction, arrives at a general formula which is a modified form of the equation of the equilateral hyperbola.

The principal results obtained by Rydberg are stated by

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* *Physical Review*, 1, 28, 1893.

† Rydberg. *Kongl. Svenska Vetenskaps Akademiens Handlingar*, Bande 23, No. 11, 1890.

him as follows: In the spectra of the elements hitherto examined the strongest rays form series which are represented to a high degree of approximation by the equation

$$n = n_0 - \frac{N_0}{(m + \mu)^2}$$

where n signifies the wave number, m the number of the ray in the series $N_0 = 109721{\cdot}6$, n_0 and μ are constants which are characteristic of the particular series.

In the spectrum of each element there are two series of doublets or triplets. These series are respectively diffuse and sharp. It addition, there is a principal series composed of doublets which approach each other as we pass to the more refrangible end of the spectrum. The principal series contains the strongest lines of the spectrum, the diffuse series is next in strength and the sharp series is weakest.

An interesting and important relation exists between the principal and the sharp series. This relation is expressed by the following formula:

$$\pm \frac{n}{N_0} = \frac{1}{(m_1 + \mu_1)^2} - \frac{1}{(m_2 + \mu_2)^2}$$

If in this formula we make $m_1 = 1$ and give successive integral values to m_2, then n represents the frequencies in the principal series. On the other hand, if m_2 equals 1 and we give successive integral values to m_1, we obtain the sharp series.

The wave lengths of corresponding lines, the distances between the components of doublets and triplets as well as the constants n_0 and μ in corresponding series in the spectra of different elements, are periodic functions of their atomic weights.

The series in the spectra of any one element are related in a way which proves that they belong to one system of vibrations. The periodic relation between the constants of the formulæ for corresponding series in different elements allows the calculation of the spectrum of an element when the spectra of the adjacent members in the periodic system are known.

Rydberg remarks that the hypotheses of Lockyer on the

dissociation of the elements are quite incompatible with the results of his researches. Lockyer's observations on *Na* and *K* only prove that with luminous atoms, as with sounding bodies, the relative intensities of emitted radiations may vary under different circumstances; for the lines in question belong undoubtedly to the same system of vibrations.

Concerning this paper by Rydberg, Kaiser and Runge make the following remarks:

They did not find his formula to be more fitting than their own, nor did they find that Rydberg's constant N_0 was an absolute constant, but that it varied a little like their B, which only varied 22 per cent. in the elements examined.

The next contribution of Kaiser and Runge deals with the second group of the periodic system.

Their results on this group were published in 1891. The series in the spectra of this group of divalent elements consist of triplets, with constant differences for each element. The series corresponding to the principal series of the alkali metals are not found, but the analogy between the series actually found and the subordinate series of the alkali metals suggested that they should be named subordinate series.

The spectra of *Mg*, *Ca*, *Zn*, *Cd* and *Hg* each show two subordinate series of triplets which end at the same point for $n = \infty$.

Sr shows but one series, and *Ba* none.*

The behavior recalls that of the alkali metals, in that *Rb* and *Cs* show but one subordinate series.

The production of the full spectrum seems to become more difficult with increasing atomic weight. In the spectra of all of the elements of the second group there is a considerable number of lines which do not fall into the general scheme.

The homologous series show the same shifting toward the red end of the spectrum that is noticed in the first

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*In 1893 Rydberg, using Kaiser and Runge's measure, found the second subordinate series of *Sr*.

group. To what extent the series of the elements are periodic functions of the atomic weight, Kaiser and Runge say they could not conclude from the small number of elements examined, but they remark that if the wave lengths for $n = \infty$ in the homologous series are used as ordinates and the atomic weights as abscissæ, a curve will be formed which is quite similar to the curve of atomic volumes given by Lothar Meyer.

In 1891 Kaiser and Runge published their results on *Cu*, *Ag* and *Au*. They found far less regularity than in the spectra of the alkali metals. The spectra of *Cu* and *Ag* show two subordinate series which end at the same point for $n = \infty$.

In addition, in both spectra there is a strong ultra-violet pair, which may be the first of the principal series. Gold shows no series, but does show the strong ultra-violet pair homologous to the isolated doublets of *Cu* and *Ag* just mentioned.

The greater or less perfection with which the series in the spectra of the elements are developed may, perhaps, be partially explained by the following consideration:

The elements, when heated to the temperature of the electric arc, are in very different relative states. The absolute temperature of all is the same, but they are not at corresponding temperatures, that is, at temperatures equally removed from their melting points. Now it is with the elements of highest melting points that the series are least perfectly developed, which would indicate that the temperature of the arc is not sufficient to bring them out. In general, the lower the melting point the more perfect is the development of series in the spectra. This fact is illustrated by the following table:

Element.	Melting Point.	Percentage of Lines which Fall in Series.
Ba	1600	0
Au	1200	4
Cu	1050	6
Ag	960	26
Sr	700	20
Ca	700	34
Mg	600	64
Zn	410	80
Cd	320	50
Li	180	100
Na	90	100
Cs	62	100
K	58	100
Rb	38	100
Hg	40	27

In 1892 Kaiser and Runge published their results for *Al*, *In* and *Tl*. As in the other groups of elements, and as had been found previously by Rydberg, they found two series of doublets in the spectra of each. These are respectively diffuse and sharp, ending at the same place, and therefore analogous to the subordinate series of the alkali metals.

In 1893 they gave the results which they had obtained for *Sn* and *Pb*, *As*, *Sb* and *Bi*. They did not find the regularity which they had established for the first three groups of the periodic system. Nevertheless, these spectra exhibit a certain order, since there are groups of lines whose frequencies differ by a constant. They state in a foot-note that *Mn* is the only element not in the first three groups whose spectrum contains two series of triplets.

In 1896 Runge and Paschen studied the spectrum of helium, and found that it resembled the result that would be obtained by superposing the spectra of two alkali metals, that is, they found two principal series and four subordinate series. They drew the conclusion that the gas consists of two elements, and adopted the names helium and parhelium for them.

In 1898 the same observers studied the spectra of *O*, *S* and *Se*. The spectrum known as the compound line spectrum of *O* was the one investigated. It was found to consist of series analogous to those of the other elements. They found six series, as in the case of helium, hence their conclusion from spectroscopic evidence that helium is a mixture does not hold. *S* and *Se* also show indications of two principal series, but each shows only two subordinate series. For the determination of the lines which belong to the principal series they used the relation discovered by Rydberg between the sharp subordinate series and the principal series. This relation is given above in the account of Rydberg's memoir of 1890, but in another form it is somewhat more easily appreciated. The relation is this: The difference between the wave numbers of the common limit of the subordinate series and the limit of the principal series is the wave number of the first member of the principal series.

Thiele published in 1897 and 1898 two papers dealing with the subject of series in spectra. The first paper states that he finds that the formula expressing the relation existing in spectra is some function of $(n + c)^2$

$$\lambda = f\ [n + c]^2$$

In the second paper he resolves the third carbon band into series.

Up to 1896, the hydrogen spectrum was considered anomalous, since it contained but one series of lines. In the above year, however, Pickering* discovered a new series of lines in the spectrum of ζ Puppis. This series ends at the same point as the well-known series of the hydrogen spectrum and is hence the second subordinate series of that spectrum. Up to the present time these lines have not been produced in the laboratory.

An important fact showing the correctness of the work that has been done in resolving spectra into series was discovered by Humphreys† in 1897. In investigating the shift toward the red end of the spectrum that is produced by

* Pickering. *Astrophysical Journal*, 5, 92, 1896.

† Humphreys. *Astrophysical Journal*, 6, 233, 1897.

increasing the pressure of the gas in which the arc giving the spectrum is placed, he found that the lines in any series have the same shift; that is, since the shift is proportional to wave length, if the shifts of the lines are divided by their wave lengths the results will be constant for all the lines in any one series. But the amount of the displacement is different for lines belonging to different series, although they may have approximately the same wave length. The first subordinate or diffuse series is shifted about twice as much as the principal series and the second subordinate or sharp series about four times as much as the principal series.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.

Stated meeting held November 8, 1899.

PHOTOGRAPHIC RECORD WORK.

DISCUSSION.

The Chairman, Dr. Henry Leffmann, announced the subject for discussion and invited Dr. Charles F. Himes to open the subject.

DR. HIMES spoke as follows:—The possibilities of photography as an art preservative were fully realized at the first announcement of its discovery. It promised to supplement the printed page in a way that the most skilful and conscientious artist could never hope to do. The authorities of the Congressional Library, at Washington, doubtless had this in mind when they very appropriately associated the names of Guttenberg and Daguerre near each other in the saloon of inventors, a fact, by the way, that seems to have escaped the notice of many at the recent meeting of the Photographers' Association of America, where, after an animated, almost indignant, discussion, resolutions were passed, and a committee appointed with power to correct the supposed omission of recognition of the inventor of photography.

Whatever may be thought of the adaptation of photogra-

phy to artistic expression, it is just that that unfits it most for art, that gives it its high value for observation and record work. The artist or the draughtsman can employ a sort of rhetoric of art, a way of putting things, to accentuate what he wishes, and with a purpose in view. He can close his eyes to the undesirable or disagreeable, but as a record his work is always necessarily incomplete; for at his best he does not and cannot give all that he sees, and what he does give is always colored by personal bias and interpretation. The camera, on the other hand, without sense of beauty or even sense of propriety, with no point to make, no preference to emphasize, with inability to reject any more than to select, is necessarily mathematically, even painfully, accurate into the minutest details, giving a complete record with the unerring precision of a machine. The importance for record of facts of this degree of completeness, so annoying to the artist, is apparent upon reflection, that as no condition in a phenomenon or experiment may be regarded as trifling, hardly even relatively so, so for the purpose of record there is no detail in the pictorial representation of a fact, however minute, that can safely be treated as trivial, or incidental. What may be misinterpreted, or entirely overlooked to-day, may to-morrow assume the highest importance, even prove to be the germ of a new branch of science. Great discoveries often spring from such incidental facts. How many inexplicable defects on photographic plates, that were supposed to have been carefully shielded in the neighborhood of Crookes tubes, turned out, in the after-light of Roentgen rays, to have been unrecognized pointers to that discovery.

Whilst the characteristics of photography alluded to were recognized at the very beginning, complete realization of expectations based upon them necessarily awaited fuller development of the art; but its progress, in very recent years, has been so rapid, in all that fits it for record purposes, that unless we reflect we can hardly appreciate its present resources in this respect, and the widened range of possible subjects. To note briefly some of these points of advance:

(1) The time required or permitted by it to make an observation and record it, for it does both, formerly within very narrow limits, to-day lies between extremes almost infinitely separated. It can record the phenomenon that lasts but an instant, which the eye cannot recognize, and, on the other hand, since the perfecting of the dry plate, it can look and look, not only with unwearying retina, but with cumulative effect, by the hour, if necessary, bringing into range of observation and record facts luminously too faint ever to come within the range of direct vision.

(2) Color has ceased to be a matter of much concern. Orthochromatic plates will reproduce the discolored, the faded, the visually indistinct, or even invisible.

(3) Local illumination, and time of day or night, have become very secondary matters in many cases, by reason of the ready response of modern plates to the various convenient artificial illuminants, as magnesium light, electric light and even gas light. Thus the interior of the pyramids and of mines, the alcoves of libraries, the well-lighted studio have become practically alike.

(4) Inaccessible places of photography have come to mean only those inaccessible to man. Freed not only from the impedimenta of tents, solutions, etc., of the olden time, but even from the changing bag and heavy and fragile glass, the camera has become equally the *vade mecum* of the glacier wanderer and the ordinary traveller.

(5) The division of labor which the modern dry plate permits allows the exposure to be made by the one who knows best what is wanted, or who may have opportunity, and the development to be made by the one whose technical knowledge and skill may elicit the best results. As an illustration from my own experience, some years ago, after having carried the camera to one of the most rugged points in Switzerland, to obtain a series of views of a glacier system, on my return, although I had perhaps as large and successful experience in development of dry plates then as most amateurs, for want of time, combined, I confess, with some want of faith in the plates, I readily committed their development to Mr. W. H. Rau, and I am fully satisfied

that he obtained delicacy of results that I would have fallen short of.

The topic, "Photographic Record Work," announced for discussion this evening, I take to be, then, the most complete utilization of photography for making and preserving records of facts—using the word fact in its broadest sense. This term has been introduced from England, where considerable attention has been given to this application of photography in the past few years, first, under the rather ambiguous name of "survey work," by local photographic associations, and more recently by the National Photographic Record Association, recognized by Parliament, with the British Museum as its depository. According to its constitution, and announcements made of its work from time to time, it is confined, almost exclusively, to work of a general historical character.

Thus, among the contributions of Sir Benj. Stone, M.P., who has been especially active, are photographs of interesting parts, relics and documents from the Palace of Westminster, of ancient ceremonies of state at the Tower, survivals of mediæval usage still observed, of municipal records of London, of the warrant for the execution of Charles I, showing many erasures, and from the Vatican archives, of love letters of Henry VIII to Anne Boleyn, as well as of the treatise that earned for him the title Defender of the Faith.

Whilst this is most important work, and is not conducted as systematically, to any extent, in this country, I think there is an equally inviting special field of activity open to the Franklin Institute, and a practical plan in operation here might be of further service in aiding, as well as stimulating, societies more distinctively historical in the prosecution of work more similar to that of the British associations. But for the Franklin Institute, peculiarly, the time seems opportune for, indeed almost demands, the beginning, at least, of a collection of photographs of scientific and industrial subjects that with time would become as unique in interest and value as the library of the Institute has become. Whilst such a collection might and should, of

course, contribute to the rescuing and fixing permanently of rapidly disappearing, or endangered, records and land marks of scientific and industrial history, by the duplication of old documents and records, photographs of historical pieces of apparatus and machinery, portraits, etc., etc., never to be acquired too soon, I think, however, the main purpose should be to make as complete, systematic, practical pictorial record of scientific and industrial facts of the day as they occur. We make scientific and industrial history as rapidly as civil history, and should be, at least, equally careful for its preservation, for, unless human nature changes, the end of the twentieth century will want to know as much and as minutely about the beginning of it as we do now about that of the century just closing. We must now be satisfied with drawings of that period, often crude, and always limited in numbers; they can expect from us no less than the increased facilities for pictorial representation of to-day entitle them to. Perfected photography, if I may so call it, has made this a picture-reading age, and it is becoming more and more a picture-demanding age. Just as the business man in this type-writing age turns, almost instinctively, from the written communication, so even the scientific man will turn more and more from the purely descriptive page to the pictorial page, which is not only abbreviated description, but by aid of photography may have much needed completeness of details and highest authenticity. As an illustration, with a local interest of its own, I have here a photograph of a piece of apparatus devised and used in investigation by Prof. Walter R. Johnson, of the Franklin Institute, about seventy years ago, which he called a rotascope. It has been appealed to, and substantiates his claim to the invention of the gyrascope some years before Foucault. Professor Johnson was appointed on the Perry Japan expedition, and sold his apparatus, which was bought by Dickinson College. For some reason, however, he did not accompany the expedition. More than thirty years ago, upon assuming a chair in Dickinson College, I encountered this strange apparatus. Professor Baird, a predecessor, then in

the Smithsonian Institution, gave me the facts as stated. I rummaged the journals of that period, found the description, figure, and account of investigations made with it. One piece—the orbital rod—was wanting. A piece of mahogany on the scrap heap was recalled, which I had had once in hand to fashion into something else, but which had been placed aside because of manifest evidence of contrivance and design. It proved to be the missing part in the performance of an experiment demonstrating the tendency of a body rotating on an axis and at the same time revolving in an orbit, to conform the axial motion in direction to that in the orbit. In connection with this, attention was called to the fact, mentioned by Biot and others as singular, that the heavenly bodies all rotate on their axes in the same direction as they revolve in their orbits, attributed to the first cause of motion, and also to geological theories based on changes in the position of the polar axis. It is in itself an exceedingly interesting experiment. The heavy wheel of the rotascope, put in motion in any position, soon assumes a position with its axis perpendicular to the plane of orbital motion, and with a motion conformable to it; and upon reversing the orbital motion, it soon wabbles with apparent discomfort, and finally reverses its vertical position, and this reversal can be effected several times before it comes to rest. The case should be capable of mathematical statement and solution. But to return to the point, from which we have been led into a longer digression than was intended by the interest incidental to the subject, the account given in the *Journal of the Franklin Institute* (December, 1831) is accompanied by a careful drawing; but it does not represent the apparatus as actually employed. Probably no piece of apparatus ever was constructed on the model figured. It may be regarded as idealized, as was not only allowable, but natural. But this photograph of the more crude actual apparatus possesses a character and authenticity, as well as historic interest, that the drawing does not. What I would suggest in cases of this kind is not that the author be deprived of the privilege of an ideal drawing, but that such drawings be supplemented, in many cases,

by photographs of the actual apparatus, not a complete edition of photographs, but at least one to be inserted with the article and the drawing in the bound volume of the *Journal* preserved in the library of the Institute. There are many other subjects even more susceptible of such photographic supplementation, which would give to the volumes of the *Journal* in the library a completeness and authenticity for record and reference not only unique, but of possible incalculable value, and at but nominal additional expense.

Among such subjects of even greater interest are many ephemeral in character, as exhibits of apparatus illustrative of processes, methods, etc., made before the Institute and its several sections, that have more than a passing interest, sometimes in connection with elaborate lectures and public demonstrations of epoch-making discoveries. Accounts of these are published in the *Journal*, reinforced as far as they can be with liberal illustrations, but such displays of apparatus, and the carefully arranged lecture table that has often absorbed much time and thought and expense, could be fixed permanently, at least as to its most important features, in a few minutes, and occasionally even some prominent scientific man, who will not live forever (in the flesh), might be caught entangled among his apparatus; though this last may be an unwise suggestion. If but a single print were made for the volume of the *Journal* in the library, and another for an independent collection of photographs of such subjects, the trouble would be repaid in a short time. Whether and in how far such photographic illustrations should be furnished other libraries or subscribers to the *Journal* might be a matter for consideration.

But such illustration of volumes of scientific periodicals, or even of books, by special photographic inserts, is secondary in importance to the accumulation of an independent, systematic, classified, indexed collection of photographs of scientific and industrial interest, from any sources, as notes for reference, and records for confirmation, arranged for convenience of reference, with proper regard for the preservation of the photographs. This last is especially important,

as the collection should consist of direct prints from the negatives, not of photo-mechanical reproductions; for although the latter have high value, they lack the quality akin to original entry, as well as the minute accuracy and possibility of magnification which belong to the photograph.

Care should, of course, be exercised in the collection for, or admission into, the collection, which, as it does not rest on pictorial value, nor even in all cases on technical excellence, but upon the record value, might contain many prosy or even at times positively ugly and inartistic pictures.

Whilst at first many subjects may suggest themselves as desirable, and efforts be made to secure them, the chief value of the accumulation will lie rather in its growth with the years, gathering up everything worth preserving, than in immediate acquisitions.

As to sizes, processes, technical excellence, etc., whilst there should be standards, recommended at least, the acceptance of any photograph offered should be based entirely on its character and desirability as a note.

There is only one other suggestion that I would desire to impress specially, namely, that provision should be made for stereoscopic pictures. It is not a question whether most or many persons are accustomed to or even can use the stereoscope, but simply as to whether such pictures have possibilities for representation and record that other pictures have not. Where position in space, or form, is to be represented, the value of such pictures is too well known to be discussed, but to emphasize the statement I submit a stereograph of a series of sparks of a Holtz machine. Either single picture presents simply a bundle of interlacing lines; both combined in the stereoscope exhibit lines of definite shape, separated and located in space. So in a single picture by the Röntgen rays there is nothing to locate an object, but by two such pictures, stereoscopically related, the object at once assumes its proper position. Soon after the discovery of Professor Röntgen I received from Professor Elihu Thompson stereographs taken by means of it, and I have here a radio-stereograph of a mouse taken by a German, which is very effective.

With this rather hurried presentation of the subject I hand it over for further discussion, knowing that there are those present who have done work unsurpassed in the reproduction of old documents and prints, and there are many points of interest to be brought out, especially the part that may be played by the representation of color in this connection.

THE CHAIRMAN:—A phase of photographic record work that has attracted but little attention, but seems to be capable of valuable applications, is the reproduction of official documents, especially those relating to property. At the present time the city of Philadelphia, for example, maintains a large force of clerks for the copying of deeds, mortgages and other papers relating to real estate. These copies are, of course, liable to error, their production takes much time and they are bulky. By photography a deed or mortgage could be copied at once and with absolute accuracy, and, moreover, in much smaller space than is now possible, which last point suggests a saving in the matter of handling and storage. Moreover, several reproductions could be made from the same negative, and kept in different places, thus rendering the loss of any set a matter of no serious moment.

MR. LOUIS EDWARD LEVY:—A photograph being in its very nature a record of the thing photographed, it follows that the subject of photographic record work is limited only by the definition of the phrase itself. If we confine this definition to the idea of recording present facts for future reference, and leave out of our purview all the many illustrative uses of photography, all its utilities as an art of graphic reproduction and all the vast domain of its æsthetic capabilities, there still remains a practically boundless field of photographic work.

Much of this field has already been surveyed by Professor Himes in his presentation of the subject. Reverting to such of its aspects as have particularly impressed me in the course of my experience, I am brought first of all to a consideration of the peculiar value of photography as a means of recording the personal data of history.

Looking around in any portrait gallery, such, for a typical instance, as the large collection of portraits from the Revolutionary epoch recently loaned by one of our public-spirited citizens for exhibition at Independence Hall, or the similar collection of pictures that hang permanently on its walls, one feels instinctively that however graphic may be these representations, they are not autographic. They are, so to speak, translations of the original theses, good, bad or indifferent, according to the competency of the translator. They bear inevitably the impress of the translator's individuality; like all translations, they render their subject in the form of a paraphrase, which may mean more or less, or something very different from the original. The consciousness which directs the artist's hand unavoidably affects, to a more or less positive degree, his perception of his living subject, and the portrait thus produced, however skilfully it may be drawn or painted, is a reflex, not alone of the physiognomy of the subject, but also of the artist's conception, or preconception of that subject. Frequently, this preconception results in a deliberate and studied idealization, admirable enough in its way, but wholly worthless as a record of the truth of nature.

In this respect there is nothing that approaches the value of a photographic portrait. Assuming it to have been produced under a normal light and through normal instrumentalities, the photograph presents its portrait record faithfully, slavishly perhaps, but still with absolute fidelity. The photographic portrait, whatever other quality it may possess or lack, has at least the one quality of verisimilitude. There is, in fact, no other province of photography so especially its own as that of portraiture. Even though the subject be unfavorably lighted or ungracefully posed, and however deficient the picture may be in its artistic elements, the photographic portrait, unless deliberately modified by a retoucher's hand, is, in its very essence, true to nature, and, therefore, true to the truth. That minute fidelity to nature, which is the most marked characteristic of a photograph, attains, indeed, a special quality of value in the case of a portrait. The subtle verisimilitude of the photographic record affords a representation of nature whose

truth and realism no artistic idealization, however well directed or well informed, can adequately replace, and where, as in portraiture, the record to be made is that of the most subtle of all of nature's expressions, the expression of human nature, the record of the camera is at once the most impartial and the most complete.

The value of photographic portraits as data for ethnological studies, and ultimately, doubtless, for sociological deductions as well, has been fully recognized by competent biologists. For scientific purposes photographic records are, of course, alone available, but the significance of such records is forcibly suggested to us when we look upon the portrait busts of Greek or Roman leaders which have remained to us, or the physiognomies of the Middle Ages as preserved for us on the coins and painted miniatures of that period, or those of the later generations depicted for us by Dürer and others of that epoch. At the present time we have photographic portraits of only two or three generations at most. The oldest of these are the daguerreotypes of some fifty years ago, and they are but few and far between, rare heirlooms of the camera's earliest days. Nowadays, however, almost every one has a picture "taken" more or less frequently, and in time these portraits, now produced in time-proof form by various processes, will afford valuable records for the scientist's use. Already our family albums throw an interesting light on the subject of heredity, and afford extensive data for such a study of that subject as that published some years ago by the late Professor Cope in the *American Naturalist.*

There is another aspect of photography as a means of recording facts that has especially come to my notice, namely, in recording topographic changes. I was recently shown by a friend a little snapshot picture, made by him last summer at Fort Sumter, looking inward towards Charleston harbor. It happened that the point of view was almost identically the same as that from which I had myself made a stereoscopic view some twenty-five years ago. Both exposures were made at low tide, and the changes which the harbor improvement at Charleston had effected in the conformation of the landspit which is visible

at low tide were very markedly brought out by a comparison of the two photographs. Another similar instance is the change produced in the brink of Niagara Falls by the erosion of the cataract, and which may now be studied in photographs made at intervals of thirty to forty years. No drawings could render this subject with such graphic detail as do the photographs, which afford a survey at once accurate and indisputable.

In fact, surveying by photography is now being reduced to a science, but I will not further dwell upon the subject. The uses of photography for the making of scientific records are as obvious as they are many, and the field of its application is constantly widening.

MR. F. E. IVES remarked that there was still one feature that had not been touched upon, namely, the importance of the element of color in some record work. He said that the kromskop system was now being successfully employed to record and reproduce colors as well as forms in disease and surgery, and quoted Dr. Keen * to show

* A demonstration of color photography at the College of Physicians of Philadelphia, by Mr. Frederic E. Ives, took place on Wednesday evening, November 1st. In introducing the inventor, the Vice-President, Dr. W. W. Keen, called attention to the value of this method of photography as applied to several departments of medicine, especially in pathology, surgery, internal medicine and dermatology. The difficulty of reproducing by drawings the exact pathologic appearances, for example, of pneumonia, apoplexy of the brain, infarct in the kidney, cancer of the liver, etc., is very great, but a good photograph by this method would give a far better and more accurate idea of the appearance to the student. The tints are exactly reproduced, so that whether it is employed in teaching or in demonstration of specimens in connection with a paper before a society, it would be invaluable. The same would apply to surgery, as, for example, the appearance of an ulcer, of an ulcerated carcinoma of the breast, of cystitis, or the varying appearances on section of carcinoma and sarcoma.

In medicine, he was a little uncertain whether the instrument was delicate enough to show the taches rouges of typhoid, though it would probably show the petechial spots of purpura and possibly of typhus. Jaundice could be well shown, the appearance of the vaccine vesicle, the differentiation between smallpox and chickenpox would be facilitated very much by such photographs. In dermatology it goes without saying that all of the affections of the skin in which color enters could be well reproduced. It would be well if our hospitals especially would furnish themselves with outfits for the purpose of taking such photographs, and great improvements undoubtedly would follow the wide use of the method.—*Phila Medical Journal, Nov. 4, 1899.*

the undoubted success and importance of such applications.

Dr. Himes:—There is one point not fully brought out in these statements in connection with the kromskop; that is the reproduction not simply of color, but of that often equally characteristic but less definable appearance of luster.

IN MEMORIAM.

WILLIAM PENN TATHAM.

William Penn Tatham, who died on August 5, 1899, while temporarily sojourning at Atlantic City, was the last survivor of five notable brothers, George N., Henry B., Benjamin, Charles B. and the subject of this memoir, who was born near Frankford, Philadelphia, in the year 1820. In 1840, the brothers formed a partnership for the purpose of manufacturing lead pipe and sheet lead, and located their establishment on Prune (now Locust) Street below Sixth Street. Their business soon grew to be of such importance as to require enlarged accommodations, which were obtained on Delaware Avenue below South Street, whereby greater facilities were acquired to meet the increased demand for the specialties they manufactured. Later, the works were removed to the building on Fifth Street above Locust, which had been especially designed for their purposes by William P. Tatham.

More machinery, of a heavier and better character, was installed, and its operation and maintenance were managed by the junior member of the firm; a duty for which he was well qualified by his aptitude for mechanics. The most important feature of their business was the introduction into this country of solidly-drawn lead pipe, and the consequent rejection of the method then in vogue, known as the "draw-bench," in which the longitudinal edges of lead strips of limited lengths were brought together and compressed into close contact, and the lips soldered to each other, and then rounded up by a die—a slow, laborious process. In the improved process, the pipe was solidly drawn

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WILLIAM PENN TATHAM.

President of the Franklin Institute, 1879–1885.

or forced by hydrostatic pressure through annular dies, which were supported in the bottom of a receptacle for melted lead. When a charge of hot metal became reduced in temperature until upon the point of solidifying, it was ejected, forcibly and continuously, through the die, in unlimited lengths of uniform diameter and without seams. This effected a material gain in time, in durability of the product, and in the quantity of stock required to produce pipe of a given capacity.

Mr. Tatham devised an improvement in the preparation of ingots or slabs, intended for rolling into sheets. These were cast in open moulds, which, on being filled with hot metal, sometimes ruptured or became distorted, and delivered the content when cooled with its edges or sides in uneven thicknesses. This disadvantage was overcome by a judicious construction of the mould in wrought iron, which retained its shape and durability. Many other devices used in the works were originated by him, and which, though seemingly unimportant in themselves, were, in the aggregate, advantageous, and added materially to the facilities of the manufactory.

Mr. Tatham traveled extensively in Spain and in other parts of Europe, also in Egypt, up the Nile; then through England, where he made many friends. On his return home, in 1850, he became a member of the Franklin Institute; in 1870 he was elected a member of the Board of Managers, and in 1879 was elected to the presidency of the Institute, and held that position until the end of 1885. He was then re-elected a member of the Board of Managers, and in 1887 was elected one of the Vice-Presidents, and continued in that office until failing health caused his retirement in 1897. During his long connection with the Franklin Institute he was constant in his devotion to the advancement of its objects, and identified himself with all its important transactions. His intimate and harmonious associations with men prominent in business affairs and in the arts and sciences enabled him to enlist their sympathy and aid in his efforts to promote the purposes of the Institute.

For fifteen years Mr. Tatham held the congenial position of chairman of the Committee on Library. His knowledge of books on general subjects of interest and on the exact sciences enabled him to make selections from new contributions to science that seemed worthy of a place in the library, and to him it was a labor of love so to enrich it with works of reference as to maintain a high standard of excellence. Among these were the completed parts of the British and French reports on patents, obtained by favor through friends residing in those countries. These publications are rare and invaluable for reference, as is evinced by their constant use not only by the members of the Franklin Institute, but also by the legal fraternity and the general public interested in inventions.

Mr. Tatham was chairman of the Committee on Exhibitions in 1874, on the occurrence of the semi-centennial anniversary of the foundation of the Franklin Institute, when the Board of Managers resolved to commemorate the event by holding an exhibition of American manufactures. The time was auspicious. The custom of the Franklin Institute of holding annual exhibitions had been departed from chiefly for the reason that there was in existence no building suited to the purpose. During the preceding sixteen years no exhibition had been held. As the initial step, Mr. Tatham was fortunate in obtaining the consent of the Pennsylvania Railroad Company to use their freight depot at Thirteenth and Market Streets, then about to be abandoned for the more convenient location at Thirty-second and Market Streets, and he at once began the needed preliminary alterations and additions, and by his unflagging energy the building was speedily put into good order, and well adapted to its intended use. For the first time in its history the Franklin Institute had ample quarters, deserving of its many displays of American manufactures. The wisdom shown in the choice of location and the promptness in securing it were admirable. The opening was happily ushered in and the broad aisles were constantly thronged with visitors from far and near, examining the greatest and most valuable collection of American manufactures that the Franklin Institute had ever secured.

The result proved gratifying to all—visitors and exhibitors—and, incidentally, also to the treasury of the Franklin Institute. The administrative ability of Mr. Tatham and his constant general supervision and attention to details, combined with his success in enlisting the willing aid of many able coadjutors, made the result highly satisfactory. In many of the previous exhibitions by the Franklin Institute the expenditures exceeded the receipts; but in this case the treasury was replenished by an unprecedented profit of over $50,000, a timely addition, which for some time relieved the Institute from the embarrassment of an insufficient income.

In the autumn of 1884, during the presidency of Mr. Tatham, the Franklin Institute decided to hold an exhibition devoted to the electric arts. Again, by his influence, Mr. Tatham secured the aid of the Pennsylvania Railroad Company in furtherance of the object, by obtaining without charge the use of the station building at Thirty-second and Market Streets and of the vacant lot adjoining it on the west side. Upon these, special buildings were erected under his direction by an active committee of the Institute, and, when completed, and the exhibits installed, it was announced to be opened to the public by introductory remarks by the President. Of this exhibition, it has been said that "Measured by its results in stimulating the progress of electrical arts in the United States, it is acknowledged by all who are engaged in the electrical industries to have been by far the most important of its kind ever undertaken."

Mr. Tatham, in 1881, began to put into shape the result of much thought expended by him on the possibility of constructing an accurate transmitting dynamometer, that is to say, the production of a machine for measuring power, which, being placed between the source of power and the machine to be operated, could be relied upon to weigh the power required to operate the driven machine apart from the frictional resistance in the dynamometer itself. The Proney brake, considered by him the most correct method of determining the power of a steam engine or a water-

wheel within the limits of the power of such a brake, does so by absorbing all the power that is given off. Dynamometers of the Morin type, which are next in accuracy, are limited in application, while many existing transmitting dynamometers include the friction of the instrument in the power indicated. The main idea of Mr. Tatham was founded on a fact not generally considered in belt transmission, that the journal friction due to the weight of the belt or the tension of the belt is constant whether no power is being transmitted by the belt, or whether the full power of the belt is being transmitted from one shaft to another. Thus a belt, transmitting power from one shaft to another, is capable of transmitting power only to the extent of the adhesion of the belt surface to the pulley surface, due to the ultimate strength of the belt and its pressure on the pulley, incident to the weight or tightness of the belt within the limit of elasticity. The dominant idea in Mr. Tatham's mind was so to arrange a belt operating in and through a weighing machine that all strains shall be balanced, the only one actual weight being the amount of force or strain that is being transmitted by the tight side of the belt on the dynamometer. The various stages through which this machine passed can be found described in the Franklin Institute *Journal*, beginning with the paper on an "Improved Dynamometer," read before the Franklin Institute, November, 1881, published in volume CXII, No. 5. A second paper on the same subject will be found in volume CXIV, December 6, 1882, in which the ideas expressed in the first paper were advanced, and the machine presented to the Institute is described in detail, with valuable notes as to the results obtained and the mode of calibrating the instrument. On page 449, volume CXX, July to December, 1885, is a description of the improved dynamometer on the same principle, constructed in 1884 for the Franklin Institute and used by the Committee of Judges at the Electrical Exhibition, June, 1884. This instrument was capable of measuring 100 horsepower, and was used to determine the mechanical equivalent of heat on an enormous scale. The water churn was a cylinder 3 feet in diameter and 3 feet long, holding 1,223

pounds of water. The result of the experiment was that the mechanical equivalent of 1° C. is 1,391·05 foot-pounds, or the mechanical equivalent of 1° F., 772·81 foot-pounds. Professor Rowland's figures are higher. In Mr. Tatham's experiment, after the exit water had been brought to a uniform temperature, the experiment proper began and continued two and one-half hours, during which over 5 tons of water passed through the churn and was raised about 15·5° C. by the continued exertion of 46 horse-power. This machine is now deposited with the University of Pennsylvania, and is used to great advantage in the Engineering Department, under the direction of Prof. H. W. Spangler, Sc.D.

Mr. Tatham was largely instrumental in the organization of the Pennsylvania State Weather Service in 1887, in connection with the U. S. Weather Bureau, which lent its active coöperation to that end. He acted as the chairman of the Committee on Meteorology during the entire period in which the Institute conducted this work, and until the transfer of the Weather Bureau work to the newly-created Department of Agriculture removed the direction of the service from the control of the committee. During this entire period, covering some eight years, Mr. Tatham was indefatigable in his zeal and industry in promoting the efficiency of this committee's work, giving to it the same thoughtful attention that he was accustomed to bestow upon every responsibility which he assumed in his relations with the Franklin Institute. Every dollar of the expenditure of the appropriation made by the State Legislature to support this work received his critical personal supervision, and the publication of the Monthly Bulletins of the service in which he manifested the greatest interest received his watchful and solicitous attention.

Among the papers that he contributed to the Franklin Institute it may be noted that as chairman he was the author of a majority report of the committee on the "Enforced Adoption of the Metric System," in place of our present system of metrology. This report was adverse to its adoption, and is worthy of note as a full yet concise history of the

subject, and a valuable contribution to its literature. In its action thereon the Institute committed itself against the enforced adoption of the metric system, but approved the legalized use of it in whatever case or under whatever circumstances it should prove most useful to those who elected to employ it.

Mr. Tatham was elected a member of the American Philosophical Society in April, 1875; he was promptly elected as a Councillor, and, in 1897, was made chairman of the Committee on Finance, and served as Treasurer *pro tem.* upon the decease of the Treasurer, Mr. J. Sergeant Price. He was also a member of the committee appointed to devise a plan for increasing the facilities of the society by enlarging the space to be devoted to the display of its books.

During Mr. Tatham's term as President of the Franklin Institute the dress sword, which was worn by Dr. Franklin upon state occasions, was devised by one of his descendants, Mr. R. Meade Bache, who was then in possession of that historic relic, to the President of the Franklin Institute. This sword had been entrusted to the care of the Historical Society until such time as the Franklin Institute could provide a safe depository for it. This interesting relic is now in the custody of the Institute.*

In his youth Mr. Tatham was intended for the legal profession, but his natural inclination urged him to follow the more congenial pursuit of mechanics. His long life-work is evidence of the fitness of his choice. He was a man of sound judgment and firm convictions, prompt and faithful in his attention to the requirements of his official duties, and was not excelled by any in his strong interest in all that appertained to the welfare of the Franklin Institute and the sustainment of its reputation.

Mr. Tatham married, in 1867, Katherine K. Biddle, daughter of James Crowell Biddle and Sarah Caldwell Keppele, who survives him.

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* The Franklin sword has inscribed upon its sheath the following memoranda: Benjamin Franklin, 1755; B. F. Bache, 1790; R. Carr, 1797; W. Duane, 1859; H. Bache, 1860; R. Meade Bache, Wm. P. Tatham, Franklin Institute.

NOTES AND COMMENTS.

A NATIONAL PARK IN THE EAST.

The creation of a great national forestry and game reserve in northern Minnesota, embracing 7,000,000 acres around the headwaters of the Mississippi River, with many lakes of rare beauty, well stocked with fish, is being actively advocated in Congress by prominent citizens of Chicago and Minnesota. The promoters of the plan are not likely to experience much difficulty in interesting Congress. The game and the virgin forests of the United States are disappearing so rapidly, that it is exceedingly important that measures be taken, before it is too late, to save some of the great wooded areas of the continent.

It is one of the marked features of the legislative and popular indifference to their best interests common to those regions that such enterprises as this never originate in our Southern States. Yet there, it would seem, we have the most promising, most adaptable and most accessible regions for such purposes to be found anywhere within our national limits. Nearly all of the forestry reserves that have been established up to the present time are in the far Northwest; the chief of them, the Yellowstone National Park, is inaccessible to the great majority of the people. Nothing of national scope is to be found east of the Mississippi River.

Within about a day's travel of New York, Philadelphia, Baltimore, Washington and most of the Atlantic seaboard, and quite as accessible to Pittsburgh, Cincinnati, Louisville, Indianapolis and St. Louis, there are vast stretches of virgin forests—along the line of the Great Smoky Mountains, on the border between Tennessee and North Carolina—that are thoroughly suited to the purposes of a great game and forest preserve. Going up from the lowlands at Walhalla, S. C., to the high plateau surrounding Highlands, N. C., a stage trip of about 30 miles, the late Professor Gray, the eminent botanist of Harvard, tells us that he encountered a greater number of species of indigenous trees than could be observed in a trip from Turkey to England, through Europe, or from the Atlantic coast to the Rocky Mountain plateau. The region surrounding that described by Professor Gray, especially to the west, with the headwaters of the Tennessee, the French Broad and the Savannah Rivers, all within a few miles of each other, with fertile valleys and mountain elevations of 5,000 feet or more, and a density of verdure unapproached elsewhere, is an ideal spot for a preserve, where every sort of North American animal or fish would thrive and where almost every tree or plant found within our borders from the Atlantic to the Pacific would grow uncared for. The land in this region is still purchasable "for a song," certainly at as little as or even less than that obtaining in the Northwest. The climate, while sufficiently severe in the winter to suit the more northern species of animal life, is never sufficiently so to kill great quantities of game, either by freezing or through lack of winter food, as is not uncommon in the Northwest woods.

Added to the climatic and the varied physical characteristics of this region,

which especially fit it for the purposes in view, there is no like region obtainable where the varied and picturesque scenery so admirably adds to the desirability of the location. While these headwaters are singularly devoid of lakes, there are ample streams running through deep valleys and gorges which render the production of artificial lakes and reservoirs a matter of detail and of slight expenditure. Cascades and even waterfalls of very considerable dimensions abound on every hand, vast stretches of virgin forests, with an evergreen undergrowth of laurel, kalmia, rhododendron, etc., afford ample shelter and browsing for the winter, while the steep mountain sides, largely covered with bowlders and rocky ledges, from every cranny of which dense vegetation springs forth, furnish safe homes for all varieties of our smaller mammals.

A park that would take in the region along the Smoky Mountains around Clingman's Dome, or the southern slopes around where North and South Carolina and Georgia meet, in the middle of the headwaters of the Savannah River, or where Tennessee, North Carolina and Georgia meet, would not be misplaced. The timber and mineral wealth of the regions mentioned are such that it can only be a question of a few decades when these mountain slopes will be denuded and when the people of the vast valleys that depend on these watersheds for their water supply will suffer from the blindness of a generation that could not foresee the otherwise inevitable and combine its prevention with the benefits of an enduring national park in the populous East.—*Scientific American.*

WASTE PRODUCTS.

In a recent paper, read before the Engineers' Club of Philadelphia, John Birkinbine presented many interesting facts relating to the utilization of waste products, one of which has special interest for tin-plate manufacturers. Mr. Birkinbine says: "The possibilities of utilizing waste in a single direction were suggested by a visit to a large button works in Connecticut, where I was informed that 90 tons of buttons had been made in one month. The material used to produce these buttons was the remnants of the sheets of tin plate from which the bottoms and caps of cans for blacking and other boxes had been cut. After the button blanks had been punched from this tin-plate the small triangles of metal connected by iron threads were compressed in a form under a drop-hammer, and subsequently shipped away to be made into sash weights."

THE MINERAL RESOURCES OF THE PHILIPPINE ISLANDS.

At a time when information regarding our new possessions is so much in demand, the memorandum by George F. Becker, of the United States Geological Survey, on the mineral resources of the Philippine Islands, will prove of great interest and value. The pamphlet, which was printed at length in a recent issue of the *Scientific American Supplement*, covers all the main discoveries in the geology of the Philippines which are of economic interest. The data were obtained from various sources, including unpublished records in the Spanish Mining Bureau, mine reports by the late William Ashburner, verbal information obtained in Manila, and from various technical publications.

The valuable minerals, as far as present knowledge goes, are confined to about a score of the islands. Luzon heads the list with deposits of coal, gold, copper, lead, iron, sulphur, marble and kaolin, while coal and gold are the two minerals most commonly found in the other islands. The Philippine Islands' coal is a highly carbonized lignite, analogous to the Japanese coal and that of the State of Washington, but not to the Welsh or Pennsylvania coals. It is thought that the native coal might be made to supplant the English or Australian coal for most purposes. Petroleum is found in Cebú, where a concession has been granted, and there are evidences of natural gas, while oil and gas are reported on Panay.

Gold is found in a vast number of localities in the archipelago. It is generally detrital and found in watercourses or stream deposits now deserted by the currents. There are placer deposits, some of which are worked in a crude way by the natives, and some of the gravels are adapted to hydraulic mining. In one of the islands a gold quartz vein has been worked, which is 6 feet in thickness and has yielded from $6 to $7 to the ton.

Copper ores are reported from a great number of localities, northern Luzon containing a copper region of unquestionable value, where the ore has been smelted by the natives from time immemorial. Other of the deposits are described as veins of rich ore 23 feet in thickness.

A lead mine has been partially developed near the town of Cebú, on the island of that name, while at Torrijos, on Marnidugue, a metric ton of argentiferous galena is said to contain 96 grams of silver, 6 grams of gold, and 565·5 kilograms of lead.

Iron ore exists in abundance in Luzon, Caraballo, Cebú, Panay and probably in other islands. The finest deposits in Luzon are near Camachin, where wrought iron is produced and manufactured into plowshares. Charcoal pig might be produced to some advantage in this region, but the lignites of the archipelago are probably unsuitable for iron blast furnaces.

Of non-metallic substances, sulphur deposits abound in Luzon and other islands, while marble of fine quality occurs in the island of Romblon and in the provinces of Manila and Marong. There are concessions for mining kaolin in Laguna province, and the pearl fisheries in the Sulú archipelago are said to form an important source of wealth.

Taken altogether, the above statement, coming from an official source, establishes the fact that the Philippine Islands have a solid mineral as well as agricultural value. When the pacification of the islands is effected a promising field will be open in the exploitation of the actual extent and value of these resources.

ARTIFICIAL SILK.

The production of artificial silk has for some time past attracted the attention of experimenters in France, and we learn from the *Scientific American* that it has been used with success to replace natural silk in certain fabrics. The Count du Chardonnet, who claims to be the first to have successfully carried out the process, exhibited some fine specimens of artificial silk at the Paris Exposition of 1889. Since then he has perfected his system, and, at

the present time, a factory of considerable importance is in operation at Besançon, under the direction of M. Tricano. This factory is now capable of producing 150 kilograms of artificial silk per day.

Natural silk is largely made up of a body called "fibroïn," together with other substances such as gelatin, albumen, wax, coloring matter, fatty and resinous matter, etc., the cellulose of the mulberry leaf being thus transformed by the silkworm. The nature of these transformations is, of course, unknown, and in order to produce a substance resembling silk, a method is adopted by which the cellulose furnished by cotton is used as a base. The cotton, having been transformed into nitro-cellulose, or guncotton, by treating it with nitric and sulphuric acids, this latter is dissolved in a mixture of ether and alcohol, and the resulting collodion is filtered under pressure.

In order to be successfully used for the production of artificial silk, it is found that the collodion must be allowed to "age" for a certain period of time, the reason of which has not been definitely settled; however, it is certain that the collodion, on being allowed to stand, undergoes certain modifications by which it is better fitted for the purpose. It is then run into cylinders, which have capillary holes in the bottom, and the collodion is forced out of these holes under a pressure of forty to fifty atmospheres. It comes out in the form of white cylindrical filaments; these are united to form threads, which are put up in skeins and all traces of alcohol or water which they may contain are removed. In this state, however, the threads are extremely inflammable, partaking of the nature of guncotton, and to remove this difficulty they must be "de-nitrated," that is to say, the cellulose must be brought back into its normal condition. This part of the process, which is indeed an essential one, involves considerable difficulty, and has been experimented upon for some time by M. du Chardonnet and others. However, a process has at last been arrived at which accomplishes this in a satisfactory manner. The details of this process have not as yet been made public; but it is certain that by this operation white silky threads are produced, which are not appreciably more inflammable than natural silk. The skeins which have been made up of these threads are then dyed by immersing them in a heated bath of basic aniline color.

PRESSED STEEL CARS.

Apropos to the paper of Mr. Loss on the "Pressing of Steel," just published in the *Journal*, the following editorial comments on the behavior of pressed steel cars in collision from the Philadelphia *Record*, will be of interest:

"The announcement which was made a few weeks ago that the Carnegie Company had contracted to supply 1,000 tons of steel a day for ten years to the Pressed Steel Car Company, of Pittsburgh, has aroused much public interest in the cars referred to, and the question has been asked more than once: 'What would be the effect of a collision or other mishap on a railroad train equipped with steel cars?' The Baltimore and Ohio Railroad, which has just passed through a long period of reorganization, was completely remodeled and modernized in its rolling stock equipment during the receivership, and when the property was finally turned over to the owners the company possessed

about 6,000, nearly new, pressed steel cars. The Master Car-builder of the Pittsburg and Western Railway (which is a branch of the Baltimore and Ohio) has had several of the pressed steel cars sent to his repair shops from the road after having been in accidents of various kinds, and his report on the condition of the cars after the roughest usage in collisions is, therefore, interesting and instructive. Among other things he says:

"'Steel car No. 4211 left the track known as our Negley stone track, which is about 10 to 15 feet higher at the point where car left track than our main line. Car went over the bank, landing on main track, and blocked the road. Our superintendent happened to be on board a passenger train which came up behind this trouble, and cleared the track by use of engine and chains. This car was under load of 100,000 pounds of crushed stone. The sides were crushed in about 18 inches, bending all the side stakes on each side of the car, and breaking four journal boxes, one brake shaft, two hand holds, one winding shaft bent, drop door attachments bent, brake levers and guides torn off, truck channel bent and brake beams torn off. The pressed steel diamond truck under this car was subjected to a great deal of rough usage in getting main track cleared, as it would be reasonably supposed that the body of car received some very rough handling to avoid delay to trains. I supposed that I would have to remove all the side stakes on account of their bent condition, but, fortunately, we made a good, first-class job by using hydraulic jacks and hammering on stakes until we got the side straightened. The material required amounted to $8.37; labor, $30.60; total, $38.97.'

"'I might also add, for your information, which is very important, that if a train of wooden cars had been subjected to the punishment to which car No. 4211 was subjected there would have been nothing left but the scrap. In this case this car was the only car damaged in the train, it being so solid, substantially built, etc., that all other cars behind it were protected. A wooden car would not have stood the punishment that car No. 4211 went through under such heavy load.'

"The statements in this report (which covers several different accidents) prove that the pressed steel car, apart from its enormous carrying capacity and consequent economy as compared with wooden cars, is also practically indestructible. Even a single car in a train acts as a sort of buffer to protect the other cars in case of accident. For these reasons we may expect to see a rapid increase in the number of steel cars in use on passenger trains as well as on freight trains. In point of fact, there is no apparent reason why the ordinary passenger cars and drawing-room cars should not be built of pressed steel. The probable reason that steel passenger cars have not yet been built is that the Pressed Steel Car Company has been in operation a very short time (about three years), and has had more orders for the construction of freight cars than it could possibly fill up to this time. Pressed steel is coming more and more into use every day as a structural material; for it has been found that with sufficiently powerful presses rolled steel sheets of considerable size and thickness can be readily pressed into any desired shape, and at a moderate cost where many duplicates of the same form are required.

"These pressed steel pieces have immense strength, and are much lighter than steel castings intended for similar purposes. The method of manufacture is simply an enlargement of the quick method of stamping sheet brass, tin or

other metal into shapes for fancy boxes, hardware novelties, bicycle parts and multifarious metal goods of small size. Car wheels have been made of pressed steel for some time past, and have given good service. The process of pressing steel seems to occupy a position midway between the rapid stamping of small or light articles from sheet metal and the slow forging by powerful hydraulic presses of red-hot ingots of steel into great guns, enormous shafts for ocean greyhounds and other similar heavy work. The process of pressing steel is, we believe, capable of development so as to cover a much wider field."

ANTIMONY IN BRASS.

In a paper read before the American Institute of Mining Engineers, Mr. E. S. Sperry has pointed out that the occurrence of cracks during the rolling of brass is due, in some cases at least, to the presence of impurities in the copper of the alloy. In certain investigations made by this author, he added to a brass composition made of 60 per cent. of Lake copper and 40 per cent. zinc, quantities of antimony varying from 0·01 per cent. up to 0·65 per cent., and tested the behavior of the alloys thus obtained in the rolling mill. He found that when the percentage of antimony reached as much as 0·02 per cent., the fracture of the rolled metal indicated its presence. W.

PROTECTIVE COATINGS FOR THE IMMERSED PORTIONS OF IRON VESSELS.

The advent of iron ships has been accompanied with a difficulty, which has not yet been met satisfactorily—the finding of a suitable protective coating for the immersed parts, to protect them from corrosion and the attachment of marine plants and animals. The latter is the more troublesome, and, especially in tropical waters, the rapid accumulation of marine growths of this nature, in the course of a few months fouls the bottom of iron ships to such an extent that the speed is reduced to one-half or even more. This, of course, materially reduces the efficiency of a vessel—especially of a naval vessel—and necessitates frequent docking for scraping and cleaning.

The old plan, generally employed with wooden vessels, was to sheath them with copper sheathing. In the case of iron vessels, however, this cannot be done without first applying wooden sheathing to which the copper can be attached, and this is a somewhat expensive operation, which, on this account, is only occasionally resorted to. Nevertheless, unless some efficient substitute for copper sheathing is not devised in the near future, this expensive method will have to be adopted.

Attempts have been made to coat the iron hulls of ships with copper electrically, by a process of electric plating on a huge scale, but those appear to be unsuccessful. Meantime, recourse has been had to the application of various paints and similar protective coatings, none of which, thus far, have proved entirely satisfactory.

The *Chemiker Zeitung* of recent date contains an instructive article on this subject, from which the following information is derived. The author

enumerates the following indispensable conditions for a protective coating for iron ships to realize the requirements of service: (1) The compositions should protect the ship's hull from corrosion; (2) they should form a smooth surface, so as to decrease the friction; (3) they should dry quickly, so that the cleansing of the submarine parts and the application of a double coating can be done in a single day. In the case of new steel vessels, the black scale on the plates must first be removed by the use of acid pickle before applying the coating, which otherwise will drop away with the scale and permit the exposed metal to rust.

The author describes several paint compositions that have been used for this purpose, and gives the preference to that proposed by Rahtjen. This process consists in employing as the vehicle a solution of shellac in spirit, to which is added some iron oxide and a small proportion of linseed oil to give it elasticity. This first or priming coat is intended to serve for insulating the iron hull, and is followed by a second one composed of the same materials with the addition of arsenic and quicksilver. The Rahtjen compositions are highly commended for their permanency, as the salt of the sea water has but little action on the shellac which constitutes the vehicle of the paints. The efficiency of the second coating as a preventive of marine growths is ascribed to the formation of mercuric chloride by the slow action of the sea water on the quicksilver contained in the composition and which acts as a poison upon the marine organisms. These paints have the further advantage that they dry quickly, so that several coats may be laid on in a single day.

The defects of the Rahtjen paints are that only a small quantity of mercury can be incorporated in the paint, as otherwise the shellac would be affected, and that the effectiveness of the paint decreases with time because of the slight solubility of the shellac.

Of the mineral poisons incorporated in these compositions, copper and mercury have been found most efficacious. Copper would be preferable on account of the cheapness, but has the objection that when the insulating or priming coat has become defective, its presence in considerable quantities in proximity to the iron hull is apt to cause rapid corrosion of the iron by galvanic action.

The author of the article above referred to gives some instructive information as to the manner in which the efficiency of such protective compositions is called into action. Thus, he explains, the purpose of the poisons in the paint is to kill the germs of the crustaceous animals, which only swim about freely during the first stages of their development, and in seeking a permanent place of growth attach themselves to the vessel's hull. While the ship is moving through the water the paint layer is being continually affected by friction, so that the sea water can enter into chemical action with the poisons of the paint, whereby there results the production of an antiseptic (germicide) compound on the surface which destroys the organisms which come in contact with it; and so long as the ship's motion is continued, fresh portions of the paint film are successively exposed with the same result. In time the antiseptic action of the paint film ceases by the exhaustion of the poisonous material, when its virtue as preventive of marine growths ceases, though the insulating coating may still protect the hull from corrosion.

Again, when the hull of the vessel is at rest, as when in harbor, the con-

tinuous formation on the surface of the paint layer of an antiseptic substance is arrested, being rapidly exhausted by the vast amount of animal life coming in contact with it, and not being renewed by frictional contact with the water, as when the ship is in motion. This is the explanation of the fact that a vessel in port (particularly in tropical waters) fouls much more rapidly than when at sea. It is observed, however, that the antiseptic agents which have thus become exhausted after a few weeks' detention of the vessel in port, again become effective after putting to sea, when the exhausted particles of the paint skin are removed by friction, exposing a new poison-saturated surface.

The whole subject of the proper protection of the hulls of iron vessels from rusting and marine growths is in a sort of transition stage, very much like that of finding an efficient substitute for wood on warships; for notwithstanding the many remedial agents that have been proposed, none of them has fully met all the requirements, and the problem still awaits its solution. W.

NON-INFLAMMABLE WOOD, OR A SUBSTITUTE THEREFOR.

The frightfully destructive character of modern naval warfare is rendered still more terrifying by the frequent firing of the inflammable woodwork by the shells that penetrate to the interior of the vessels, and there is an urgent demand for a non-inflammable wood or for some efficient non-inflammable substitute, by all the navies of the world. There is no dearth of processes for rendering wood non-inflammable, and some of them doubtless are possessed of merit, being well adapted for use in ordinary construction, where slow burning is practically all that is needed for reasonably good fire protection; but when subjected to the extremely severe conditions demanded on shipboard, none of these products have succeeded in withstanding the tests. The British Admiralty, some time ago, subjected a number of these processes to careful trial, and with the result stated above. A trial of this nature is said to have been made on the U. S. Cruiser "Brooklyn," which also proved unsatisfactory, the treated wood having been removed and replaced with untreated wood. The German naval authorities also have given the subject anxious attention, but thus far no satisfactory solution of the problem has been found.

The products that have thus far been employed seem to have been made in part by the processes in vogue for preserving timber, such as impregnation with iron, copper or zinc salts, and in part by impregnation with such well-known fireproofing compounds as tungstate of sodium, phosphate of ammonium and the like. For one reason or another, however, such methods of treatment, while answering for the service for which they were first intended, prove to be unsatisfactory for naval requirements.

It has been suggested to try the efficacy of substitutes for wood, but in this direction also the experiments that have been made have given equally unsatisfactory results.

Here would seem to be a promising field for the inventor. The conditions to be met by such a substitute are toughness, lightness, resistance to wear under foot, non-inflammability, non-conductivity for heat, and freedom from liability to splinter under shell fire.

At one period it was thought that wood might be largely dispensed with in the construction of warships, and this idea was carried out in the building of one of the large English battleships, but it was found to be quite impracticable to do away with wood or some similar non-conducting sheathing in the interior of such vessels, since the bare metal, almost always dripping with moisture in the interior, is likewise found to be extremely cold in winter, and unendurably hot in summer.

The German naval authorities seem to have reached the conclusion that the most practical course to pursue, at least until some satisfactory process for fireproofing, or an efficient substitute for wood has been devised, is to restrict the use of wood in the construction of their warships to the smallest possible amount. To what extent they have succeeded in doing this will appear from statements lately made by Herr Dietrich, Conductor-in Chief of the German Navy, which are abstracted from recent impressions of *Cassier's Magazine.* "Wooden deck planks are no longer laid; steel deckplating is covered with linoleum, sometimes over a layer of cork. In the crews' quarters the sides of the ships are not ceiled, in the officers' rooms the ceiling is made of steel sheets, lined with cork. For cabin bulkheads the steel is covered with thin woolen cloth, and with cork lining underneath, where it is desirable to deaden sound or to lower the temperature * * *. All wood is removed from the ammunition rooms save the racks for shells and powder charges. * * * For all ladders and steps steel is used * * *. Chart houses and captains' rooms are made entirely of steel and fitted out with non-combustible materials. Since all such changes will be a little exaggerated, it seemed to be advisable to abandon wood for the interior fittings, and especially for the furniture, and to resort to fireproof material which will not splinter. Many things were tried; furniture was made of steel and aluminum lined with cork and covered with linoleum or canvas, but it was not equal to wood furniture. Only the bedsteads are constructed of iron, steel or brass. The insignificant quantity of wood in the few pieces of furniture when ignited is not considered a dangerous source of smoke, which is confined to the rest of the outfit of the staterooms—the mattresses, blankets, clothing and books."

This seems to be carrying the exclusion of the dangerous element of interior woodwork on warships to the very lowest practicable limit, and, next to employing an efficient substitute for it, is doubtless the best practice. The difficulties in the way of devising such a substitute, although very great, are by no means insurmountable, and it would not be surprising, in view of the very general interest now being taken in everything pertaining to naval affairs, if an early solution of the problem were found. W.

REMARKABLE USES OF PEAT.

One of the most interesting and attractive exhibits at the Vienna Exposition of last year was a building containing the most diverse articles made from peat. Everything in the building, from the carpets on the floor to the curtains at the windows and the paper on the wall, had been made from peat. These were but representatives of what will undoubtedly soon become a great industry and give to the peat bogs of the world a value never before dreamed of.

Credit for the discovery of the possibilities of peat belongs chiefly to a Vienna gentleman, Herr Karl A. Zschörner. His investigations into its nature began some twelve years ago with a study by means of the microscope of what is called in Austria "torfstreu." This is the layer of moss which covers the surface of most peat bogs. It has hitherto, by those who have made use of the peat for fuel, been, at considerable expense, removed and thrown away. Herr Zschörner's examination showed that the plant remains which make up this layer abound in hollow spiral cells. These absorb water and other fluids with great avidity. While ordinary straw cannot absorb over four times its weight of fluids, this peat straw will absorb ten times its weight. The peat straw, moreover, possesses the antiseptic and disinfectant qualities of peat, qualities which have long been known, but of which little use has been made. Herr Zschörner accordingly hit upon the idea of drying the straw and using it as an absorbent in stables, breweries and various manufactories. For such purposes it proved most admirably adapted, and the demand for the product soon grew large. Having greater absorptive power than ordinary straw, the peat straw can be used much longer in any given place and yet will have proportionally greater manurial value. It gives a healthy, resilient footing also for animals. For packing of both perishable and breakable articles it is also better than ordinary straw, since it is more elastic and less easily penetrated by heat and cold. Another form of peat which was found to be a better absorbent for some places was the peat itself, dried and ground to a powder. This is especially adapted for use in earth closets and about sinks and drains, its absorbent power and disinfectant properties making it admirably adapted for these uses.

Herr Zschörner did not rest his investigations here. A further study of the peat itself showed that it was very largely made up of fibers These fibers come from the remains of reeds and grasses, which, growing and dying in successive generations, form the peat. In their submergence the reeds and grasses suffered no anatomical change, but their physical and chemical character became entirely different. The organic substance of the plant became inorganic, so that nothing capable of fermentation or decay was left, while the fibrous structure remained intact. These fibers then were found to have unusual physical properties. They were found to be very durable, very elastic, to be non-conductors of heat and non-combustible.

If a fabric could be woven from them, it would be one possessing unique properties. To the toughness of linen it would add the warmth of wool, an absorbent power greater than that of cotton, and the indestructibility of asbestos. It must, however, be woven without the aid of oils or water, or much of its value would be lost.

After twelve years of experimenting, Herr Zschörner succeeded in making the peat fibers weavable. There is now, therefore, scarcely any textile article which cannot be made from peat. Coats, hats, carpets, rugs, ropes, matting and pillows are some of the articles which have been made, and have been found useful. What superiority these will prove to have in practice over fabrics made from other fibers, only time will tell. Some of them have, however, already been proved to be immensely superior to any other fabrics. This is especially true of the blankets and other coverings used for horses and cattle, for they greatly excel in warmth, absorbent power, cleanliness

and durability. The unspun fiber promises to be a valuable substitute for absorbent cotton, since it will not only absorb a much greater quantity of blood and other fluids than cotton, but it possesses powerful antiseptic properties as well. The coarser fiber, it is expected, will come into favor for use in upholstery work, its extraordinary elasticity making it most valuable for this purpose.

The latest achievement of the discoverer of the uses of peat has been the making of paper from its fiber. This has been carried to such an extent that paper of almost every variety of weight and quality can be made, while the toughness and durability of each is equal to that of paper from any kind of vegetable pulp. The above are but a few of the uses to which this remarkable fiber can be put, but they indicate possibilities which may yet rank peat bogs among the most valuable of the world's resources.—*Oliver C. Farrington, in the Scientific American.*

CALCIUM.

M. Moissan, of the University of Paris, who has been successful in the extraction of the rare metals in the electrolytic furnace, has recently undertaken, according to the *Scientific American*, a series of experiments with the metal calcium, which, although abundantly distributed in nature in the state of carbonate, sulphate, etc., has not, up to the present time, been prepared in any considerable quantity in the pure state. It will be remembered that at the commencement of the century Sir Humphry Davy was the first to establish the exis'ence in lime of a metallic body, and, by decomposing it by an electric current in the presence of mercury, he obtained an amalgam of the metal calcium. Later on, in 1855, Matthiessen electrolyzed a mixture of chloride of calcium and chloride of strontium, and thus obtained small globules of calcium having a yellow color. A few years later Jobin prepared the metal by a purely chemical process, causing the metal sodium to react upon iodide of calcium in fusion contained in an iron crucible; however, the quantity of metal obtained was small, 300 grams of iodide giving but 6 to 8 grams of calcium globules. After other experiments, scarcely more advantageous, M. Moissan has been the first to obtain a relatively considerable weight of the metal. He employs two methods; in the first, which is purely chemical, he utilizes the property which calcium possesses of dissolving in liquid sodium at a dull red heat. In an iron crucible of 1 liter capacity are placed 600 grams of anhydrous iodide of calcium, together with 240 grams of sodium. The whole is heated to dull redness, at which temperature the sodium unites with the iodine of the iodide of calcium, and the calcium set free dissolves in liquid sodium, which is in excess. Upon cooling it crystallizes in the middle of the mass of sodium, and by proper separation one may obtain brilliant hexagonal crystals of pure calcium. The amount of the latter is equal to 50 per cent. of the theoretical weight contained in the iodide, and 40 grams have been obtained at a single operation.

The second process employed by M. Moissan consists in the electrolysis of iodide of calcium in fusion at a dull red heat. A cylinder of pure nickel is used for the negative electrode, and for the positive a rod of graphite. The

calcium thus prepared has been examined as to its physical and chemical properties. Among its physical properties may be mentioned the following: It may be melted in vacuo at a temperature of 760° C., and then appears as a brilliant liquid. After cooling, the metal is rather soft, and may be cut with a knife. It may be broken by striking it, and the fracture presents a crystalline structure. Its surface, when it has not been attacked by gases, is of a clear white color, approaching that of silver. Its density is 1·85.

As to its chemical properties, calcium when brought to redness unites with hydrogen, forming a crystalline hydride; it combines with chlorine at 400° C., and with bromine and iodine at a dull-red heat. In oxygen the metal, when raised to 300° C., gives a brilliant combustion. It decomposes water at the ordinary temperature, and also decomposes sulphurous acid gas with incandescence. When heated in carbonic acid gas, it becomes covered with a deposit of carbon. Calcium combines with sulphur at 400° C., and burns with incandescence in the vapor of phosphorus. It unites with carbon in the state of lampblack below redness, and produces calcium carbide. Calcium when cold does not unite with nitrogen, but when heated in that gas it absorbs it slowly, and the metal, at first brilliant, assumes a yellow color. This explains why the alloys of calcium, which up to this time were regarded as the pure metal, were all more or less yellow, this color being due to the nitride. The latter compound is obtained in transparent crystals of a yellow-brown color, melting at 1200° C.

THE RAPID DECLINE OF GEYSER ACTIVITY IN YELLOWSTONE PARK.

Prof. E. H. Barbour, of the University of Nebraska, in a recent address on the subject, affirms that, if the present apparent rate of decline continues, it seems likely that within a decade many of the scenes which attract us most will have disappeared. It was his privilege to visit the National Park on August 5, 1895, and again on August 5, 1899, and certainly the evidence of change during these short years seems startling. To the geologist the change is serious and impressive. It may be said in a general way that there is an apparent decline of geyser phenomena everywhere throughout the Park.

To be more specific, without entering into many details, it may be stated that around the splendid terraces at the Mammoth Hot Springs, buildings now stand where there was steaming water in 1885. Spots which we photographed in 1895, standing shoe soles in water, are now either dry or nearly so. Minerva Terrace, which was boiling and which presented a fine array of geyserite in 1895, is falling into decay. Large blocks of the "formation" are falling from the rims and sides of the basins. To the eye the amount of water which flows over Pulpit Terrace and Jupiter Terrace is noticeably less.

We should say not one-half what it was four years before. The lattice work, constructed for the purpose of spraying and incrusting curios, was changed to a new spot where water was still flowing. The narrow gauge, which may be called a fissure vent, though still showing life, is extinct as compared with conditions four years ago. Roaring Mountain is still steaming, though silent. In the Norris Geyser basin the most obvious change is

in the Black Growler, which formerly emitted volumes of steam from an oblique vent by the roadside. The steam jet is now divided and the volume of steam and its roar and display of energy greatly diminished. The Fountain Geyser, which was such a favorite that the Fountain Hotel was located at that spot, is now wholly extinct, and tourists are complaining because they must waste time stopping at this hotel. The Fountain has been replaced by a new but very inferior substitute, named the Dewey Geyser. Tourists do not care to wait to see it in eruption. The giant paint pots are now so contracted in size that one can walk over what was a short time ago boiling mud. The red half is extinct; the white half active, though reduced in area. In the Upper Basin there is evidence on all sides of activity, but with many changes since 1895. Then the Splendid Geyser was attracting attention. Now it is silent and considered extinct. It is replaced by the Daisy Geyser, an interesting but vastly inferior substitute. The Cascade Geyser, another favorite, because of the frequency of its eruptions (about every fifteen minutes), has dropped to an eruption interval of once every twenty-four hours.

The Grand Geyser, which used to erupt once a day, has been active but three or four times the past season, according to all accounts. The Beehive Geyser, active in 1895, is supposed to be wholly extinct. Old Faithful seems as fine as ever, but the interval of eruption is now about seventy-five or eighty minutes instead of once an hour. If it is possible to judge fairly of such matters, there seems to be increasing activity in the ebullition of the water in that greatest of geysers, the Excelsior, which leads to a feeble hope that it may possibly be rejuvenated yet once again. In this connection may be mentioned the apparent increase in the activity of the Mud Geyser, by the thumb. The mud, which in 1895 was thick, and thrown up in large masses but a few feet, is now thinned and ejected as far as the road, a distance probably not far from 200 feet. At first thought it seems like increased activity, yet it may possibly be accounted for on the ground that the mud is in a condition making more active ejectment possible. A great quantity of mud has been thrown out recently, as much as 8 to 10 feet thick, and the trunks and boughs of the neighboring pines are loaded and weighed down with mud. Trunks were noted where the coating of mud halfway up to top exceeded 6 inches. The front half of the crater is now built up symmetrically with the other side, making a very regular funnel-shaped crater about 100 feet across, and some 25 or 30 feet deep. Below, the mud is in a state of constant and active ebullition. Possibly this case may be construed as a case of increasing activity; however, on the whole it is only too obvious that there is a serious decline, as one can see by observation, and can learn by consultation with the drivers, guides, tourists and officers at the barracks. It was the testimony of all that the changes were much more rapid than is understood, and our closing admonition is, visit the National Park at once.

Franklin Institute.

(*Proceedings of the stated meeting held Wednesday, February 21, 1900.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1900.

President JOHN BIRKINBINE in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 32.

Mr. Howard B. French was elected a member of the Board of Managers to fill the vacancy caused by the resignation of Dr. Herbert M. Howe.

The President announced the Standing Committees for the current year.

Mr. Frank Hart, of New York, presented a communication on "The Development of the Cotton Industry in the United States, with Especial Reference to the Influence of Machinery upon its Growth."

The special purpose of his address was to emphasize the great importance of modern methods of handling and baling cotton as compared with the old and wasteful methods which, until recently, were exclusively used. The round lap baling system, which is now rapidly coming into general use throughout the cotton-growing districts of the South, obviates practically all of the objections of foreign manufacturers, while, at the same time, it permits of enormous savings. Mr. Hart affirmed that, if universally used, it would result in a saving of $45,000,000 on a 10,000,000 bale crop.

Mr. William C. Henderson, who has only recently returned from an extensive tour through this region, followed with an address on "The Cape Nome Gold District of Alaska." In his conclusions he strongly discouraged the idea that immense fortunes are to be made by pioneering this district, affirming that all the valuable gold-bearing territory in the region has been claimed and staked and even reclaimed and restaked again and again, so that the prospects confronting new-comers are most unfavorable.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, February 7, 1900.*]

PROF. EDGAR MARBURG in the chair.

The following reports were adopted:

Braiding Machine.—Andrew V. Groupe, Philadelphia.

ABSTRACT.—This invention is the subject of letters-patent of the United States, issued to applicant, numbered and dated, respectively, 588,421, August 17, 1897. It relates to that class of braiding machines wherein two sets of bobbins revolve around a common center, but in opposite directions, and, by the aid of complementary devices, cause the threads that pay out from each

bobbin to pass over and under each other, forming a braided cord, or a platted covering for a cord or other cord material, such as laces, shade-cords, braided ropes, whips, etc. "The essential feature of this invention consists in the construction and arrangement of a sectional trackway for the carriers of one set of bobbins, and in the mechanism for actuating said carriers, whereby the threads of the other set of bobbins are directed in an easy course between the adjacent track-sections and over and under the same and the carriers thereon, in a manner to minimize the friction of the coöperating parts and to insure a practically uniform tension on the respective threads, thus increasing the speed of the machine, and, perforce, the quality and quantity of the material produced thereby."

The model examined by the investigators was capable of doing good work at three times the speed of the common braider.

The report concludes as follows :

"In the 'sectional trackway' of this invention, in combination with a sinuous slot, through which the traveling threads pass freely over and under the inner bobbins, is found the one hitherto missing, but very essential, device that was needed to make this type of braider mechanically successful ;" and in recognition of this ingenious contribution to the art, the John Scott award is recommended. [*Sub-Committee*, H. R. Heyl, Chairman ; Luther L. Cheney, J. Logan Fitts.]

Process for Face-Hardening Rails.—Charles H. Priestley, Wilmington, Del.

Horseless Carriages.—Job Albert Davis, Philadelphia.

These two reports were made advisory.

The following reports were considered :

Pneumatic System for Preventing the Bursting of Water Pipes by Freezing.—N. Monroe Hopkins, Washington, D. C.

Electrical Switch.—Paul Medary, Cynwyd, Pa.

Micro-Stereoscopic Camera.—John G. Baker, Philadelphia.

Portable Photometer.—Charles Deshler and Edwin J. McAllister, Newark, N. J.

Water Heater for Range Boilers.—Adam Heller, Baltimore, Md.

Rail Joint.—Harry Wellenoweth, Philadelphia. W.

SECTIONS.

CHEMICAL SECTION (Photographic and Microscopic Branch).—*Stated Meeting, Tuesday, February 6th.* Dr. Henry Leffmann in the chair.

The subject for discussion was "The Applications of Photography and Microscopy to Medico-Legal Work."

The theme was discussed by Prof. W. M. L. Coplin, Prof. Arthur W. Goodspeed and the Chairman. The subject was illustrated with the aid of the stereopticon, the microscope and an X-ray machine.

The Executive Committee reported, as the result of a conference with a committee of the parent section, that no objection was made to the proposition to reorganize the Branch as an independent section, whereupon a resolution was unanimously passed, addressed to the Committee on Sectional Ar-

rangements, requesting that the seventy-nine members constituting the present Photographic and Microscopic Branch of the Chemical Section be granted the privilege of organizing the Section of Photography and Microscopy. W.

Stated Meeting, Tuesday, February 20th. Vice-President Lyman F. Kebler in the chair. Present, twenty-eight members and visitors.

Mr. B. H. Morrison presented a communication on "The Chemistry of Paper," which was illustrated with numerous specimens of the raw materials, pulps made by the several methods in vogue, chemical substances employed in the art, and a series of lantern views and photographs illustrating the various branches of the manufacture.

Dr. Leffmann exhibited an exceedingly characteristic test for the presence of wood pulp in paper, and some extremely old books and newspapers to show the excellent state of preservation of the paper.

Mr. Henrick Anderson discussed with Mr. Morrison some of the technical details of the manufacture of wood pulp. W.

MINING AND METALLURGICAL SECTION.—*Special Meeting, Wednesday, January 31st.* President Joseph Richards in the chair.

Dr. David T. Day of Washington, D. C., made a communication on "The Modern Uses of Fullers' Earth." The speaker exhibited a number of samples of clays found in the United States, which closely approach in composition and in physical characteristics the typical English clay which gives the name to this variety. Dr. Day described the uses of the material, other than in the fulling process. The most interesting of these is for the refining of oils.

Mr. William Griffith, of Scranton, Pa., read a paper on "The Flushing of Culm into Anthracite Coal Mines," illustrated by numerous lantern views exhibiting the method employed. The speaker clearly explained the value of the process in preventing the caving in of the surface ground, and as a means of effectively disposing of the great accumulations of refuse. W.

Stated Meeting, Wednesday, February 14th. President Richards in the chair.

Prof. John Gifford, of Cornell University, gave an extemporaneous address on "Forestry in Europe and America," illustrated with numerous lantern views.

The speaker specially dwelt upon the great care and attention bestowed upon the forests and forest industries in Europe, especially in France and Germany, contrasting this with the extremely wasteful methods in vogue in nearly every portion of the United States. He believed that the subject was now beginning to receive enlightened attention, and that the forest and its industries would in time be intelligently cared for. W.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting, Thursday, February 8th.* Dr. Wahl in the chair.

Mr. H. DeB. Parsons, of New York, read a paper on "Fire Hazards," illustrated with numerous lantern views.

The speaker pointed out the common defects of construction in office and factory buildings, which greatly increases their liability to destruction by fire. W.

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THE FRANKLIN INSTITUTE.

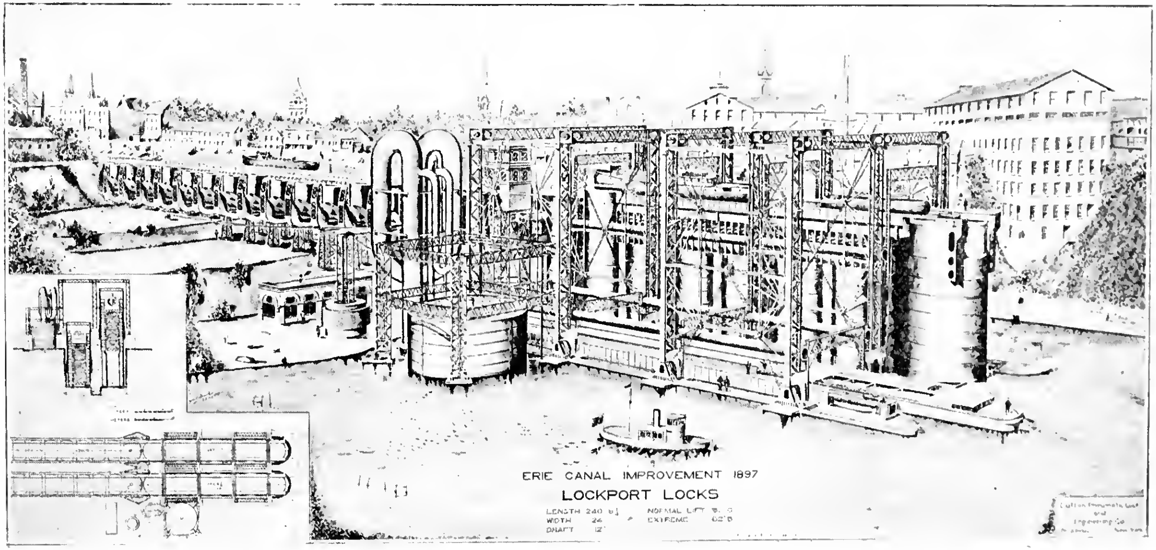
Stated Meeting, November 16, 1897.

THE DUTTON PNEUMATIC BALANCE LOCKS FOR CANALS.*

BY CHAUNCEY N. DUTTON, NEW YORK,
Member of the Institute.

These locks float on compressed air confined in their lower open-bottomed air chambers, whence it displaces water. Each lock carries a gated tank containing sufficient water to float the boats. When one lock descends the other ascends, the descending lock expelling air from its air chamber into the

* An address delivered before the Franklin Institute, Philadelphia, November 16, 1897, on the "Pneumatic Balance Locks," approved by the State Engineer and adopted by the Canal Board of the State of New York, to replace five pairs of lift locks at Lockport, and two pairs of guard locks between Lockport and Buffalo; and sixteen pairs of lift locks, known as "The Sixteens," at Cohoes, on the Erie Canal, in New York State. Revised by the author for publication.


ERIE CANAL IMPROVEMENT 1897
LOCKPORT LOCKS
LENGTH 240
WIDTH 24
DRAFT 12'
NORMAL LIFT
EXTREME

air chamber of the ascending lock through a 13-foot, valve-controlled connecting type. No compressed air is discharged into the atmosphere or wasted. The moving force is an excess of weight in the descending lock, in which the draft of water is 1 foot greater, such "surcharge" being 330 tons. The greatest energy-rate is 1,150 horse-power; the average, 115 to 150 horse-power.

At Cohoes, the lift is 144 feet. At Lockport the normal lift is 57 feet 5 inches, and the extreme lift, when floods raise the upper level, 62 feet 5 inches. The least draft is 12 feet; the width, 28 feet at the bottom and 30 feet at the top; the clear or effective length, 310 feet.

They will pass up-stream two boats drawing 12½ feet and carrying each 1,350 tons, or 2,700 tons of cargo per lockage; and down-stream two boats drawing 13½ feet and each carrying 1,450 tons, or 2,900 tons of cargo per lockage.

They will make their stroke in one minute, and, allowing for entry and exit, are expected to detain boats eight to ten minutes.

The locks are built of steel.

Each has an upper, gated lock chamber, and a lower, open-bottomed air chamber containing compressed air, on which it floats, and as the volume of its air-charge is varied, moves up and down in a pit or deepened portion of the lower level of the two which they connect.

The locks are kept from tilting sidewise by guides, and from pitching endwise by an automatic leveling apparatus, consisting in fixed racks, anchored to terra firma; parallel racks built on the locks, and hollow built-up shafts armed with pinions, which mesh with the opposite parallel racks, on which they hang, without other bearings, and between which they roll when the lock moves.

The air chambers are so proportioned that they automatically differentiate the air pressure, so that the lock which descends forces the elevated lock up against its anchors with an effort exceeding by one-third the weight of said lock and its load, so that it may be connected with the upper level, and used in the roughest manner with entire safety.

The devices to retain the elevated lock against the unbalanced hydrostatic pressure, and the gates and other parts which are liable to ramming, will sustain ramming by boats going 3 miles per hour.

If injured boats sink in a lock, it can be used as a dry-dock.

The locks can be raised clear of the water for painting and repairs.

At Lockport each lock weighs 1,500 tons, and will contain over 4,500 tons of water. The weight in motion exceeds 12,000 tons.

The first locks at Lockport, opened in 1825, passed boats 3 feet 5 inches draft, 14 feet 5 inches wide, 78 feet 8 inches long, carrying 80 tons. They were replaced about 1838 by the present stone locks, which pass boats 6 feet draft, 17½ feet wide, 98 feet long, carrying 250 tons. These locks are in a remarkable state of preservation for old limestone masonry exposed to our northern winters. The stone shows little decrepitation, and most of the joints are still tight, showing that the cement was good.

About 1880 the system of towing double-headers was introduced on the Erie Canal, from the Illinois and Michigan Canal. In this system two lashed boats form a towing unit, the stem of the rear boat being pivoted on the stern of the forward boat, and the lashings carried around pulleys and a capstan, by which the rear boat can be swung like a rudder 98 feet long. Two or three such units are towed in a fleet of four to six boats. The cheapness of the system induced the State of New York to adopt, in 1885, the policy of lengthening the Erie Canal locks, so that the two boats could enter without being uncoupled. Forty-one locks have been lengthened; but the five locks at Lockport, three at Newark, four at Little Falls and eighteen between Cohoes and tide water have not been lengthened, their location making it impractical. When the late State Engineer, the Hon. Campbell W. Adams, and his deputy, Herschell Roberts, C.E., took office, in 1894, they grappled with the problem to lengthen the unlengthened locks, or to find a suitable substitute for them. They examined the hydraulic and other types of mechanical lift locks

then in use, decided that no one of them was adaptable to Erie Canal dimensions and traffic and commenced studies of the problem, which finally led to the adoption of the pneumatic lock.

The 1895 session of the New York State Legislature passed a bill appropriating $100,000 for the construction of mechanical lift locks at Lockport; and another, $77,500, for similar locks to replace locks 21 and 22, near Schenectady.

The Governor vetoed the Lockport appropriation, the appropriation for the lock near Schenectady was deemed insufficient, and no work was done at that time on either. The same Legislature referred to the popular vote, an act authorizing a credit for $9,000,000 for improvement of the State canals, which was adopted by a large majority at the November election. Within the month State Engineer Adams ordered the preparation of three sets of plans for mechanical lift locks at Lockport. In his report for 1896, p. 25, he says:

"Three sets of plans for this work have been developed, and one of the conditions which all have been designed to meet is that the adopted plan should be capable of economic installation either at Lockport, Newark, Little Falls, or Cohoes. Two of these plans provided for suspending the lifting troughs by cables, and operating the same by two distinct hydraulic methods, but on the completion of the estimates the cost of either of these plans was found to be too excessive to warrant their adoption. The other plan, which has been adopted, depends upon compressed air for its operations. Owing to the probability that several important features in this plan will be considerably changed before the work is advertised for letting, I do not deem it advisable at this time to go into any detailed description of the plans and method of operating, but prefer to leave the subject until the next annual report, in order that it may then be carefully and fully discussed and illustrated. The adopted plans have been prepared by Chauncey N. Dutton, C.E."

The new locks were to be located to one side and in advance of the existing locks, so that they could be completed and put in operation without stopping the use of the old ones. This called for considerable extra expense and the construction of a steel aqueduct, 393 feet long. to connect the locks with the upper level.

These are the only locks between Lake Erie and Rochester, and it was, therefore, deemed advisable to make them of such size that they would give Rochester practically as good a connection with Lake Erie as Lake Ontario ports

have through the Welland Canal. The scale was, therefore, enlarged from 6 x 17½ x 98 feet to 12 x 24 x 240½ feet. This scale has been again enlarged by the Advisory Commission on Canals of New York State to 28 feet clear width at the bottom and 30 feet at the top of lock chambers, with a net or effective length of 310 feet. When the locks are installed, boats can voyage between Lake Erie and Rochester more quickly and cheaply than between Lake Erie and Lake Ontario ports *via* the Welland Canal. It is expected to build up a large trade in transit between the Susquehanna Valley, in Pennsylvania, and the Great Lakes, at a considerable reduction on present freight costs.

The detention at the present locks is frequently several hours, and never less than one hour, because the fleets have to be broken up. The new locks will pass double-headers in eight to ten minutes.

The present stone locks cost $698,000. The first estimate for the steel locks, made in December, 1896, was $576,000, but when the completed plans were adopted by the Canal Board, June 24, 1897, the estimate was put at $499,000. The market prices of steel and machinery fell sharply in the interim, but have now advanced, and when the enlarged locks are put under contract, which will be when the Legislature makes appropriation for them, the work will cost about $1,000,000. The Cohoes locks will cost one-half more.

It will be seen that the new locks at Lockport will cost about one and five-eighths the cost of the stone locks. They will handle units twelve times as large in one-sixth of the time. The dollar invested in them has, therefore, more than forty-four times the earning power of the dollar invested in stone locks.

The characteristic features of the locks may be described briefly as follows:

(1) Compressed air is substituted for water as the element of translation and support of the locks and vessels. Increasing the height of lift does not increase the pressures, and, therefore, locks of any height are practicable and much cheaper in first cost and in operation than a flight of low lift locks.

(2) The working pressures are very much reduced, the maximum being about one and one-half times the draft.

(3) The motion of translation is uniform, having no tendency to accelerate, being regulated by the velocity at which air can pass through the conduits with the given head.

(4) The locks have absolute immunity from falling. The pneumatic lock falls up, if it falls at all. It is pressed up firmly against the anchors with an effort much greater than the weight of the lock and its load. If the anchors yield, the lock is forced up to a height such that the air in the air chamber is expanded to equilibrium with the load, and a volume of water equal in weight to the difference between the load and its initial excess of buoyancy enters the air chamber.

(5) The speed can be very great, because air flows at high velocity with a slight head.

(6) Working the locks in balance, by slight differences in weight, saving 95 per cent. of the water heretofore used, and avoiding heavy currents in the canal sections.

(7) The water-trap valve for controlling the air conduit.

(8) The powerful automatic leveling, or synchronizing gearing, of construction cheap, such that the price per pound does not increase with increased power.

(9) Dispensing with the dry-dock necessary in other types of lift lock and operating the locks directly in the lower level of the canal, in a pit; the pit in which the locks work being part of the lower level.

(10) The substitution of steel, mainly in tension, for masonry in the lock structures.

(11) The substitution of elastic resistance for mere stability due to dead weight, and the consequent reduction of strains due to shock, so that they can be taken care of economically.

The principal elements of design are:

(1) The locks, which float and work in a pit formed in the lower level, and are identical structures, each having an upper gated lock chamber for the vessels and water to float them, and a lower open-bottomed air chamber containing the compressed air on which they float.

(2) Valve-controlled air conduits for transferring air from one lock to the other during translation.

(3) Anchorages to restrain the superbuoyant elevated locks.

(4) Guiding structures to prevent the locks from tilting sidewise.

(5) Automatic leveling, parallel motion, or synchronizing apparatus, to keep them from pitching endwise.

(6) A pneumatic accumulator, which is connected with the elevated lock and maintains a constant working pressure therein, automatically compensating for changes in density and temperature of the adjacent atmosphere.

There are other important elements connected with the locks, which, while desirable, are not absolutely essential, namely:

(7) Hydraulic stops and accumulator-intensifier, by which the elevated lock can be perfectly controlled and adjusted in position.

(8) An interlocker, or sequence machine, which orders the operations incident to the motion of the locks, by means of valve-controlled compressed air transmissions.

(9) Automatic stop machines, one geared to each lock, adjustable to varying water levels, which prevent the locks from running away and automatically control the variations in depth of water when elevated.

A recital of the difficulties will aid in forming a clear conception of the motive and functions. A lock is the heaviest of engineering structures, carries per square foot a load greater than the load per running foot of the heaviest railroad bridge, and is subject to tremendous and cumulative distorting forces, which necessitates that the structure be of simple type and extreme power, and automatically leveled and controlled by apparatus strong enough to beyond peradventure arrest distorting forces in their incipiency and annul their cumulative tendency.

The locks are liable to be bumped and rammed and to have boats carry away the outboard gate and sink with the boat's nose overhanging the end of the lock. A boat in this position,

half the length of the lock, or a boat of said length sunk in one end of the lock, would overload that end with a weight equal to the weight of the boat and cargo. The leveling, or synchronizing apparatus, must be powerful enough to sustain this distorting effort and distribute it, and, furthermore, it must be automatic, for were the least interval of time to intervene between the application of the distorting forces and the action of the leveling apparatus, the loaded end would pitch, the water would run off the opposite end and pile up in the loaded end, giving a cumulative effect, combined with shock, which must inevitably destroy any non-automatic apparatus, how strong soever it might be, and ruin the lock.

DESCRIPTION OF THE LOCK STRUCTURES.

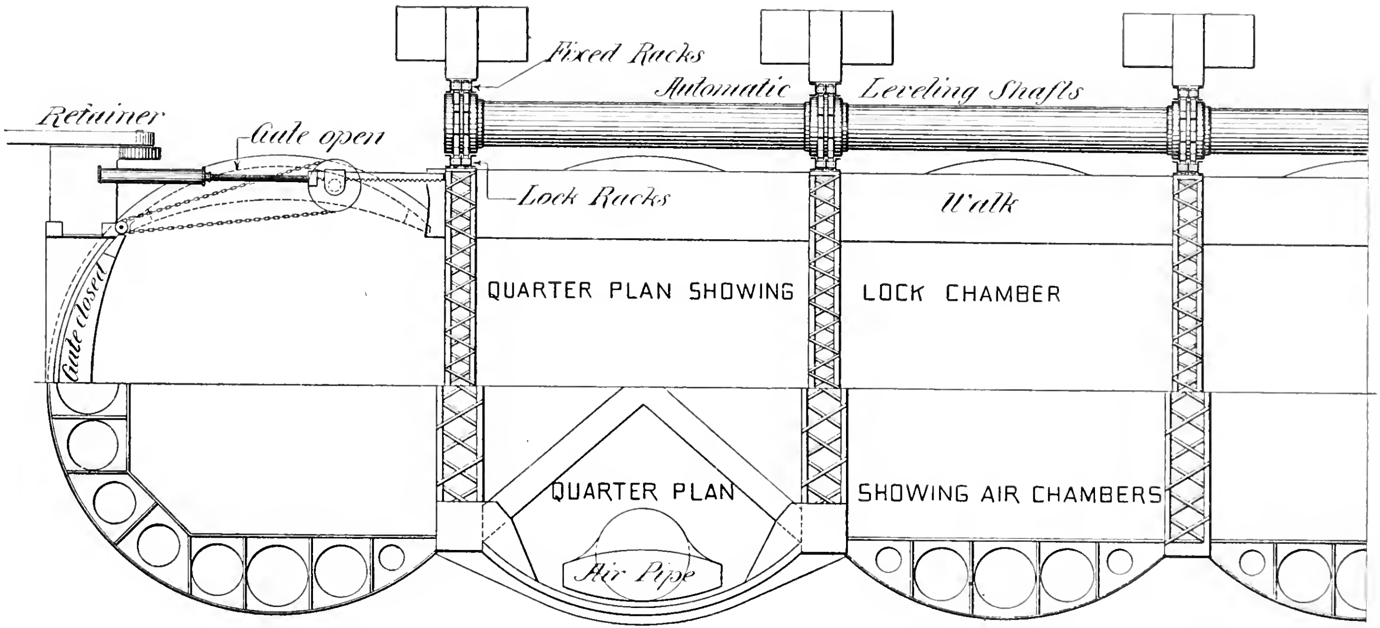
The lock structures are identical. The lower part is an open-bottomed air chamber, the roof of which forms the floor of the gated lock chamber.

The air chamber is formed in eight bays, to avoid beam strains and framing in the side walls, which are segments of cylinders tied transversely at the points of intersection. The cylindrical segments do not quite meet, being united by longitudinal plates, and the ties are in double lines, so that by lacing them together stiff transverse strut members can be formed where desired. Strut members are so formed at the bottom and at two intermediate horizontal planes, where chord plates are united with the walls, so that the entire chamber is a huge box girder. In its normal uses the walls and cross-ties are subject to tension only, and are in equilibrium, not tending to change their form, but accidental extraneous forces may tend to cause compressive strains, which the structure will sustain.

The roof of the air chamber, which also forms the floor of the lock chamber, is framed on heavy plate girders.

The hydrostatic pressure on the side walls of the lock chamber is sustained by brackets; those on opposite sides being tied by the floor plates.

The gates are crescent-shaped box girders, moving orbit-


Fixed Racks
Automatic Leveling Shafts
Retainer
Gate open
Lock Racks
Walk
Gate closed
QUARTER PLAN SHOWING LOCK CHAMBER
QUARTER PLAN SHOWING AIR CHAMBERS
Air Pipe

ally on a wheel, and when open lie out of the way in segmental side pockets.

The seating faces are concentric with the vertical axes about which the gates move orbitally.

The gate-opening engines have each a cylinder 14 inches bore, 8 feet stroke, the piston moved by compressed air, the piston rod carrying a cut steel rack, 4 inches pitch, 7 inches face, which meshes with and turns a pinion keyed to one end of a shaft, on the other end of which is a sprocket wheel geared by a Yale & Towne $\frac{9}{16}$ inch chain to a sprocket wheel on a vertical shaft, secured in bearings on the gate post. This driving shaft has spur pinions at top and bottom, which mesh with pin-wheel segments on the gate. When the piston moves, the connected rack turns the shafts and pinions and operates the gate.

The gate is lightened by a flotation chamber, which floats 74 per cent. of its weight, leaving 26 per cent. on the wheel to give stability. The air which fills the flotation chamber is constantly renewed, so that the gate will not get logy.

The gates which are liable to be rammed contain elastic trusses, with a yield of 10 inches, which cushion the blow and deliver it to the gate posts, so that ramming has no effect on the gate itself until the elastic trusses are broken.

The gate openings are slightly wider than the locks, so that the jambs are not liable to ramming, being protected by the guard timbering on the lock walls, which is as elastic as possible, to that end being supported in the centers of the plates on rubber cushions, so that the effect of impact is distributed over a number of brackets and lessened by the elasticity of the guard timbering, its rubber supports and the plates.

When the lock is elevated, as aforesaid, it is superbuoyant, having an excess lift exceeding the accidental increase of load which might occur through the sinking of a loaded boat, and this excess lift is restrained by anchors, which are steel plates secured to the bed rock, and encased in asphaltic concrete piers. On them are built the side guides and the fixed racks of the leveling apparatus. These are disposed

in four transverse lines at the end and alternate intermediate intersections of the bays.

When the ascending lock comes to rest, its momentum is absorbed without shock, by hydraulic stops swiveled on the anchorages, with which the elevated lock engages, by brackets armed with timber contact pieces, which are readily movable, to allow the lock to be raised clear of the water for painting and repairs.

AUTOMATIC LEVELING, OR SYNCHRONIZING APPARATUS.

During the years which have been devoted to developing the pneumatic lock, many different types of leveling apparatus were considered and more or less worked out, but were all prohibitive in cost, especially on a large scale. The characteristic features of that adopted are that it is always in action; has only rolling friction, normally sustains only its own weight, has the minimum wear and abundant end clearance, which prevents binding and temperature strains. It can be made of any power, and the larger it is made, the less will be its cost per pound. It does not require nice workmanship, or careful adjustment. It is what engineers call a "brute."

Its elements are vertical racks securely anchored to terra firma, parallel racks built integral with the lock; hollow riveted steel, rolling shafts parallel with the locks and carrying pinions which mesh with the opposite parallel racks on the lock and on terra firma, the shaft having no bearings, but hanging upon its engaged teeth. When the locks move, the shafts roll between the racks and traverse one-half the stroke of the lock.

The preferred form of rack is the ladder type, with pin teeth. Small lock pinions may be cast. For large locks they must be built up of rolled steel, the core a forged drum, the blanks rolled steel rings with involute cut teeth. Such a gearing would give undue wear, were it always subject to maximum working pressures, but for a lock it is, perhaps, the ideal form, as normally the teeth carry only the weight of the shafts; the maximum pressures, due to accidental unequal loading, being infrequent. In the Lockport

locks the shafts are 4 feet in diameter, made of inch plate.

The pinions are double, cut on rolled blanks, 6 inches thick, the involute teeth 16 inches pitch, 60 square inch section at pitch line, 16 pinions and 960 square inches of metal in the teeth being in action.

The outside rack stringers are 15-inch channels, with inch webs, and the teeth 6-inch pins, riveted in.

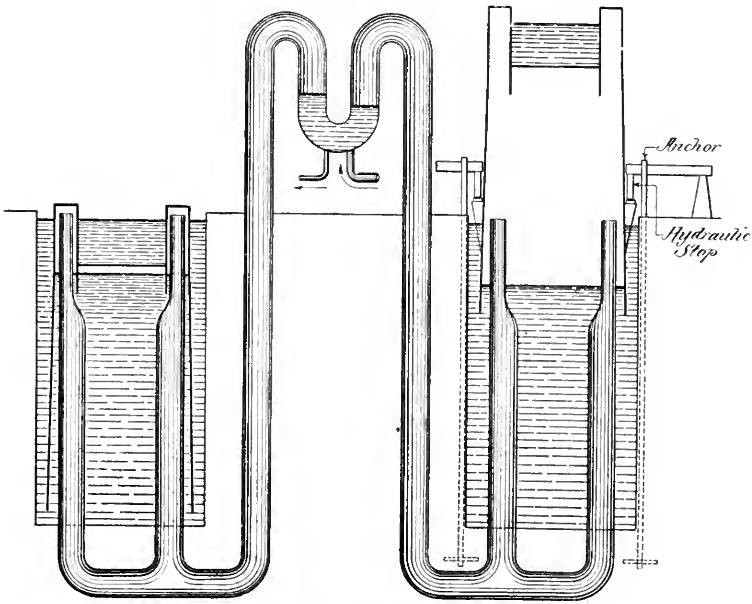


DIAGRAM SHOWING
AIR CONDUIT AND VALVE

AIR CONDUITS.

The air main is 13 feet in diameter, and will transfer the entire air charge from lock to lock in one minute, with 330 tons surcharge in one lock.

The connection with each lock is by two open-ended standpipes, 10 feet diameter, which extend from the bottom of the lock pit considerably above the water surface, under hoods formed in the lock body. From their ends rock-cut tunnels run to the risers, which connect with the main valve.

The main valve is a "U" bend, provided with water inlet and drain pipes, so that the bend may be trapped with water and untrapped to shut off or permit the flow of the air.

The water-supply and drainage to and from the valve is controlled by pneumatic weirs, which are the reverse in principle of the air valves. A water-feed pipe extends from the upper level of the canal to the lower part of the main valve, and is formed like an ∽, with upper and lower bends. A simi-

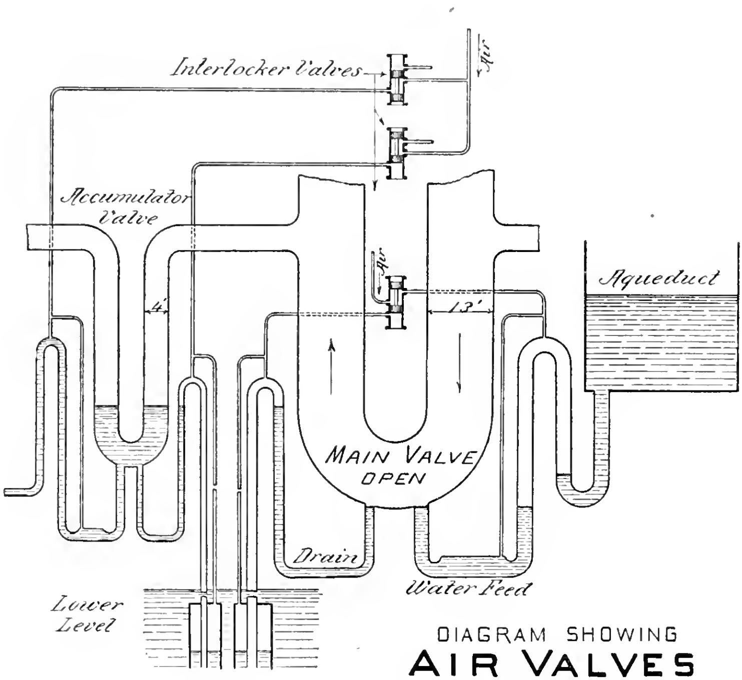


DIAGRAM SHOWING
AIR VALVES

larly formed drain connects to the bottom of the main valve, rises to an upper bend and descends into and is sealed in the water of the lower level.

Air-supply pipes lead from the upper bends of the said water-feed and drain pipes to a 6-inch double-acting air valve, which is part of the interlocking machine in the operator's house. When this 6-inch air valve is moved to "feed" the air to the weir of the water-feed, and to "waste" the air of the

drain weir, the air pressure enters the upper bend of the feed and seals it against the pasage of water; at the same time the air pressure wastes from the upper bend of the drain and the water drains out of the main valve, opening it to the passage of the air.

When it is desired to close the main valve, the 6-inch air valve at the interlocker is moved to "feed" the air pressure into the weir of the drain and to "waste" air from the weir of the feed.

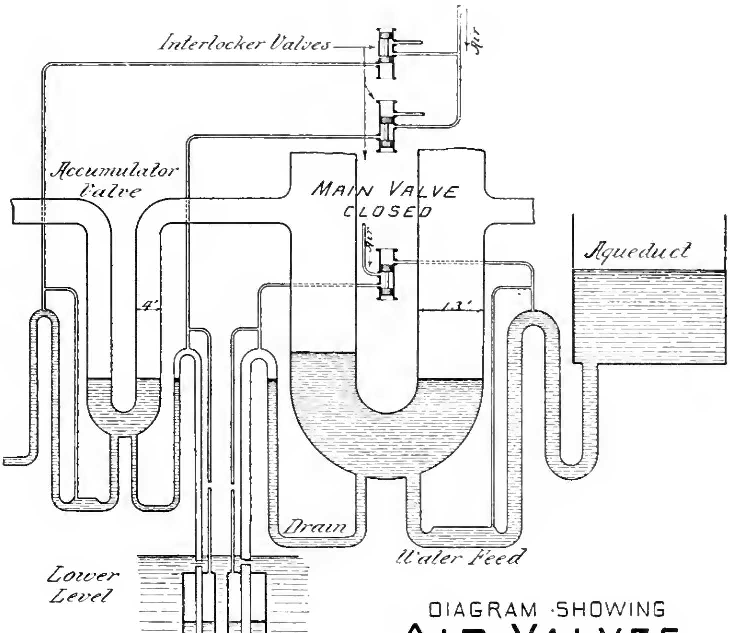


DIAGRAM SHOWING
AIR VALVES

The air escapes from the feed weir and permits water to flow from the upper level into the main valve and seal it, and such water seal is prevented from escaping by the air-trap in the upper bend or weir of the drain.

Similar valves, 4 feet in diameter, open into the legs of the main valve and connect by a 4-foot main with a pneumatic accumulator, which may be thereby connected with or cut off from either lock.

PNEUMATIC ACCUMULATOR.

The pneumatic accumulator is a cylindrical bell, or open-bottomed air tank, having an upper weight chamber filled with water, and gives a constant working air pressure. When a lock is elevated it is immediately connected with the accumulator, which maintains a constant working pressure and automatically compensates for varying density and temperature in the adjacent atmosphere, which would otherwise vary the working pressure.

INTERLOCKING APPARATUS.

In order to prevent the operator from making mistakes, all the operations necessary to translate the locks are controlled by an interlocking apparatus, or sequence machine. This machine has five levers, on vertical interlocked stems, which are geared to horizontal shafts carrying cranks directly connected with the stems of air valves, so that when the operator swings a lever he directly operates an air valve, and at the same time locks the lever behind him and unlocks the lever in advance, in order of sequence.

All the transmissions are by compressed air, and are controlled by the aforesaid valves of the interlocker, and critical motions are further controlled by stops operated by compressed air piped to them from valves at the gate posts, so that if any gate be off its seat the apparatus is firmly locked and cannot be moved until each and every gate is properly seated.

The interlocker is in a three-story operator's house, all the valves and pipes being in the lower, the operating story containing only the levers and the table which carries them.

The tubular valves have balanced spools, cup-leather packings and bronze-lined shells.

AUTOMATIC STOPPING MACHINES.

The automatic stop machines prevent the locks from rising too high, or running away, and control the amount of surcharge taken on the elevated lock, which is the working force

of the system. To this end they control the hydraulic valves of the hydraulic stops.

Because air is elastic, the motions of the ascending and descending locks are not exactly synchronous, the ascending lock leading the descending lock. Therefore, stop machines are independent for each lock. They operate only when the lock is in the upper limit of its stroke, and are adjustable to compensate for varying heights of water in the upper level.

Each lock operates its machine by chain gearing turning its main shaft, which carries a drum having a differential thread, one end being of 1-inch pitch, the other 36-inch pitch, the latter cut in an enlarged part, the slow thread being idle, merely keeping the parts in mesh while it is not desired that the lock should function the machine.

The thread moves a sliding bar, which has on one face a differential tooth meshing with the thread of the drum, and on the other an operating face, consisting in a rack and plain guiding surfaces coincident with the pitch lines of the rack. Engaged with this bar is a pinion segment, having a toothed portion and plane faces tangent to the pitch circle.

During the greater part of the lock stroke the differential tooth meshes with the slow thread on the drum, the plain faces of the bar and segment engage, and the machine does not function. When the lock approaches the upper limit of its stroke, the differential tooth meshes with the quick thread, the rack meshes with the toothed portion of the segment, and the machine functions; the shaft carrying the segment being connected with a parallel crank shaft by double gearing, the gears on the crank shaft being loose and rotating it by ratchet gearing, so that it is always turned in the same direction, whichever way the segment may be rotated. One end of the crank shaft connects by a crank and link with the main hydraulic valve. The other connects with a positive differential crank motion directly actuated by compressed air from the interlocker, and such that dead centers are avoided and the slip of the valve is taken up twice during the complete cycle. The lock opens and closes the hydraulic valve by rota-

ting the segment. The operator opens the said valve, takes up slip, and brings it to a fixed position by admitting compressed air to a piston of the differential apparatus, which is so geared that when the differential crank rotates 144°, the valve crank rotates 210°, and when the lock rotates the valve crank 150°, completing its revolution, the differential is rotated 216°, and completes its revolution.

HYDRAULIC ACCUMULATOR INTENSIFIER.

This machine gives the operator perfect control of the elevated lock. It is so designed that by operating a valve it will give either a higher or lower working pressure. When the lower pressure is admitted to the hydraulic stops, the lock will retract the stops and raise the accumulator weight. When the higher pressure is admitted to the stops, they will force down the lock.

The weight is a tubular concrete block, with an annular water tank for increasing the load. The frame is central in the well of the weight and sustains the hydraulic members, which are a lower 20-inch cylinder, a 20-inch ram carrying the weight and bored to form the cylinder for an upper 11½-inch ram working therein.

The two cylinders are connected by a valve-controlled pipe. When the valve is closed, all of the water expelled from the 20-inch ram is piped to the hydraulic stops, the pressure being 1,086 pounds. When the valve is open, one-third of the water expelled from the 20-inch cylinder goes into the 11½-inch cylinder and intensifies the pressure, raising it to 1,623 pounds.

This is an example of work equivalent. The work done is the descent of the accumulator weight. If all of this work goes into the stops, their work collectively is equal to the volume swept through by the acumulator ram at low pressure. If but two-thirds of the water passes to the stops, and one-third goes to the intensifier, it is evident that the same work must be done by the stops in a stroke two-thirds of the stroke of the weight, and, therefore, the pressure must be increased one-half.

The machine is also a mechanical proof of the mathe-

matical summation of series. In the case given the intensifier ram is practically one-third the area of the accumulator ram. Therefore, when the valve is opened, the pressure in the accumulator cylinder reacts through the intensifier cylinder, and raises the pressure in the accumulator one-third. This one-third reacting in the same manner, raises it one-ninth. The one-ninth increase raises it one-twenty-seventh, which raises it one-eighty-first, which raises it one-two-hundred-and-forty-third, and so on to summation:

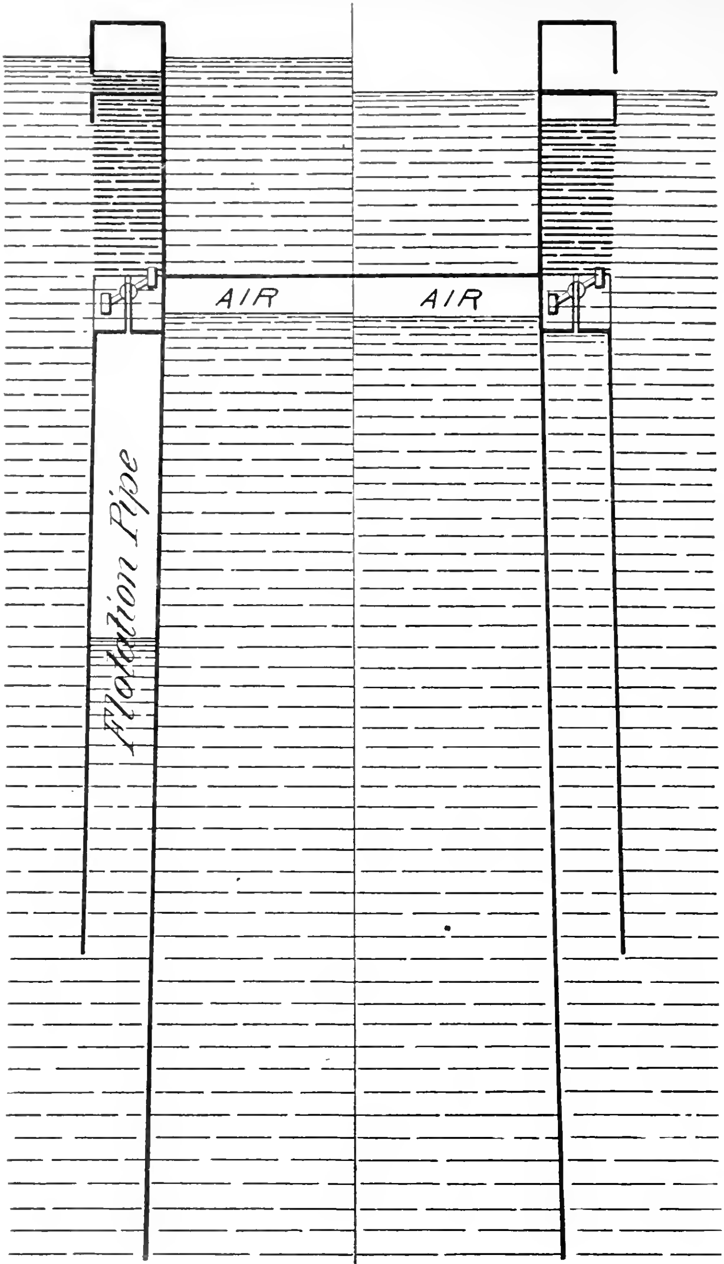
$$\frac{1}{3} + \frac{1}{9} + \frac{1}{27} + \frac{1}{81} + \frac{1}{243} +$$

et cetera, the sum of which is one-half.

OPERATOR'S CONTROL OF THE ELEVATED LOCK.

Swelling the Boats In and Out.—Experience proves that the entry and exit of boats to and from locks is much easier if water flows with the boats. Therefore, the ascending lock holds a depth of water considerably exceeding the least working draft, and when it approaches the upper limit of its stroke is automatically stopped, with the water in the lock chamber on a level with that in the aqueduct, so that as soon as the space between the adjacent lock and aqueduct gates is filled with water the said gates can be opened, without adjusting water levels, thus making a great saving in time. A further saving is made by swelling the boat out into the aqueduct. To do this, the operator moves a lever at the interlocker, which opens the main hydraulic valve, the intensifier valve being at such time closed, whereupon the lock retracts the hydraulic stops, rises and discharges its surplus water into the aqueduct, swelling the boat out, the upward motion of the lock being properly automatically arrested by the automatic stop machine.

As the boat which is to be locked down enters the lock, the operator swings a lever in the interlocker, which simultaneously opens the hydraulic valve and the intensifier valve, bringing the intensifier into action, the hydraulic stops forcing down the lock, which takes on a surcharge of water, which swells in



LOCK FOUNDERED

LOCK AFLOAT

Ready to ascend

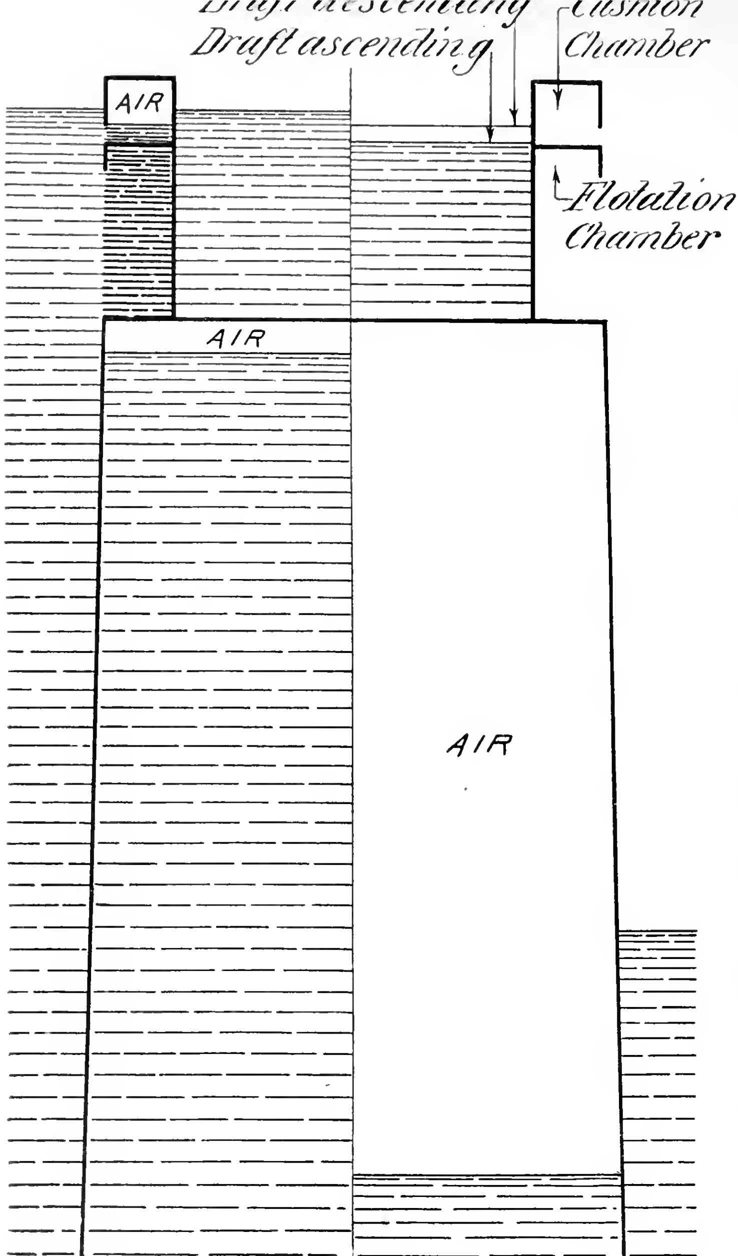
the boat, the downward motion being properly automatically stopped. If now the gates be closed, the elevated lock is ready for its traverse.

AUTOMATIC CONTROL OF THE DEPRESSED LOCK.

In order to avoid nicety of adjustment and loss of time in connecting the depressed lock with the lower level, said lock founders until its downward motion is arrested and cushioned by the floating power of the cushion chambers at the sides of the lock chamber. There are longitudinal flotation chambers beneath the cushion chambers, from which the air is discharged as the lock is immersed, so that the lock may founder; after which both gates are opened, so that water can come in behind the boat, as it is drawn out, giving it free motion.

The lock descended surcharged with water and now contains a maximum draft. In order to ascend, it must be lightened. For this purpose there are vertical long flotation pipes, of small cross-section, which, when the lock is elevated, communicate with the atmosphere and take in a charge of air at atmospheric pressure. As the lock descends this air is held and compressed, its pressure being a maximum and its flotation a minimum when the lock is in its lowest position; at which time valves are automatically opened, permitting this air to rise from the narrow vertical pipes to the long horizontal flotation chambers. As it rises, the water pressure on it diminishes and it expands to nearly atmospheric pressure and regains its original volume and maximum floating power, automatically increasing the flotation of the lock so that it floats with just the desired depth over the sill.

The minimum draft is 12 feet. Draft ready to ascend, 12 feet 6 inches. After the lock is elevated and connected with the aqueduct, it rises 6 inches, expels this surplus into the aqueduct, swells out the boat, and has its minimum draft over the sill. To take in the surcharge of water and swell in the descending boat, the lock is forced down 18 inches and descends with 13 feet 6 inches over the sill.



LOCK FOUNDERED

Load & Air Pressure Maximum

LOCK ELEVATED

AUTOMATIC INCREASE AND EQUATING OF AIR PRESSURE.

While the lock is moving, it is obvious that the air pressure cannot vary greatly from the pressure which would be in exact equilibrium with the load. If the walls of the chamber were parallel, the working margin of excess pressure must be greater, because the pressure of equilibrium would necessarily increase as the lock rose and the immersed portion of its walls became less; therefore, the locks are equated, so that the working pressure or pressure of equilibrium is constant, the sides being splayed, so that the projected area against which the pressure acts increases in a constant ratio from the upper towards the lower portion of the air chamber, with the decreased immersion of the walls.

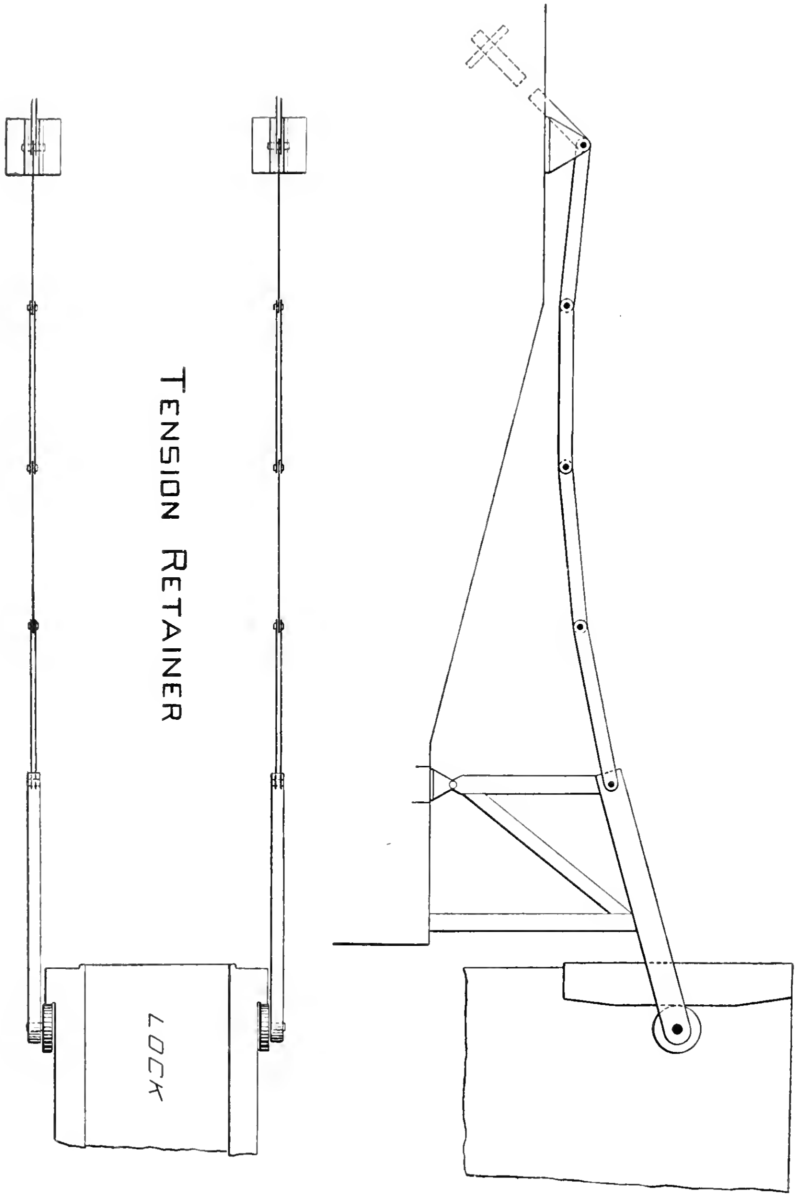
When the elevated lock is arrested by the stops, it is necessary for its safe use that the air pressure and the flotation be increased some 30 per cent. This is done automatically by the descending lock.

The horizontal area of the air chamber is considerably larger than the floor of the lock chamber, such excess equaling the sums of the areas of the horizontal segmental projections of the air chamber beyond the line of the lock chamber. When the lock is elevated, there is no water on these plates, but as the lock descends they become immersed, and the weight of water upon them is necessarily carried by the air charge, the pressure of which is thus increased and becomes a maximum when the lock is at its lowest position; and this automatic increase of pressure is transmitted to the elevated lock, and there acts on the larger pressure surface at the lock bottom, and thus automatically provides the excess of buoyancy necessary to safe use.

ELASTIC RETAINER FOR ELEVATED LOCK.

While the lock is moving it is not subject to disturbing forces, except that of the wind, but when it is elevated and connected with the aqueduct, the unbalanced hydrostatic pressure tends to force the lock away and break the joint; and because boats might ram the outboard lock gate, it is necessary that

the connection have flexibility to cushion the blow. These ends are compassed by tension retainers, which are I-bar cables, 220 feet long, hanging in catenaries, anchored at one



end to the bed rock, at the other retaining the hydrostatic pressure in the end of the aqueduct, or in the lock when connected, the connection being retaining wheels, 12 inches thick, 5 feet diameter, with 15-inch journals, adjustable in bearings formed in the end frames of the retainers, the wheels engaging shoulders on the lock, which are runways planed on heavy steel castings, riveted into and forming flanges of the portal columns of the lock body. A blow will pull the cables into flatter curves, the endwise motion cushioning the shock.

The joint is made water-tight by a dilatable rubber tube, secured to the aqueduct face, and seating at any point on a flat timber apron provided on the adjacent end of the lock. The tube is cured flat, and remains so when deflated. To make a joint, it is inflated by compressed air admitted from a valve of the interlocker. The space between the gates is flooded and emptied through pipes controlled by pneumatic weirs, which, in turn, are controlled by air pipes leading to valves at the interlocker.

POWER PLANT.

There is a 36-inch double-balance turbine, belted to a duplex air compressor, to a four-cylinder, high-pressure hydraulic pump, and to a dynamo for lighting. Also a high-pressure air tank, and a tank for the hydraulic supply, it being intended to operate the hydraulic apparatus with 500° test petroleum.

AQUEDUCT.

The necessity of operating the old locks while the new ones were being built compelled the use of an aqueduct, 393 feet long, to connect them with the upper level. This aqueduct is so designed that the strains due to the static load oppose and cushion the strains induced by collision of vessels using the aqueduct. This principle develops the full elastic quality of the steel, makes the sides four times as flexible, and the flange strains less than one-eighth as great as those obtaining in aqueducts heretofore designed; the builders of which appar-

ently ignored the destructive effect of shocks or assumed that the boats could be drilled so as not to collide.

In structures of the old type the flange strains in the frames are due to the sum of the static and shock moments, and the elastic cushioning movement of the side walls is that due to the variation in the one kind of strain, for example, tension, to which the flange is subjected. In the design exhibited, the flange strains are equal to one-half the difference between the static and shock moments, and reverse from tension to compression, or *vice versa,* so that the elastic movement is four times as great, the greatest which the metal is susceptible of without injury.

GENERAL PRINCIPLE OF CONSTRUCTION.

The floor is not framed, but suspended at the edges, and the weight thereon exerts an inward pull on the frames in opposition to the hydrostatic pressure on the sides. By suitably proportioning the parts, these forces can be given any desired ratio. The inward moment of the floor exceeds the sum of the outward moments, and induces compression in the upper and inner flanges, and tension in the outer and lower flanges below the floor line. When a boat strikes the side, the stresses are reversed.

This particular design could not be applied to the end bays, where the gates are located. Therefore, the principles were applied in a different manner, the flat floor being carried by transverse girders spliced to the side walls, which are framed as girders and connected to the inner vertical flanges of the frames which are suspended from their outer flanges on links and pins, so that under the static load the outer and under flange is in tension, and the upper and inner flange in compression. When the boat strikes one side, its shock is cushioned by the elasticity of the entire frame, and before it can have a destructive effect, it must reverse the strains in both flanges, swing the end of the aqueduct to one side and somewhat raise it. This design can be made much more effective with an equal weight than that adopted for the intermediate bays, because the shock is cushioned by the elasticity of the

entire frame, whereas the other design cushions by the elasticity of half the frame.

As the designs for the aqueducts have been very materially improved since this address was delivered, the reader is referred, for full information concerning them, to U. S. patents 621,470, of March 21, and 626,321, of June 6, 1900, issued to the author.

While every precaution has been taken in the design to prepare the structure safely to resist a maximum shock, the interior of the aqueduct is protected with elastic timber guards, which, if they be properly maintained, will absorb the greater part of the shocks without much strain to the structure. But, obviously, a structure which may be put into the keeping of incompetent men, appointed for political purposes without regard to their fitness, must be so designed that no fool can cripple it, so that it might be wrecked by improper use. Therefore, the aqueduct is designed with such great care, and is much more costly than would be desirable were it owned and operated by a private corporation, which would exercise reasonable care in its use and maintenance. The same is also true of the locks.

HOW THE LOCKS WORK.

The depressed lock floats and requires no care. The elevated lock is connected with the pneumatic accumulator, and the air pressure in it is $8\frac{1}{8}$ pounds per square inch, which expels from it a weight of water 30 per cent. greater than the weight of the loaded lock, giving it the excess buoyancy necessary to its safe use; said excess buoyancy being restrained by the anchors. When the elevated lock first ascended, it engaged with the retainer, the joint was packed by inflating the rubber pipe, the space between the lock and aqueduct gates was flooded with water, the gates were opened, the boat was swelled out into the aqueduct, to accomplish which the hydraulic valve controlling the stops was opened and the lock retracted them and raised 6 inches. As the descending boat entered the lock, the intensifier was brought into action, the lock was forced down 18 inches and took on its surcharge of

water, swelling in the boat, such lock motions being automatically stopped by the stop machine. The gates of the depressed lock, and the adjacent gates of the elevated lock and aqueduct can now be closed, and the space between them drained. The accumulator valves are now closed, the main valve is opened, and the air expands from the elevated lock into the depressed lock, raising it and at the same time lightening it as it rises, by reducing the extraneous load of water on the projecting horizontal segmental plates at the tops of the air chambers. This function continues until the air in the elevated lock has expanded to less than equilibrium with the weight thereoi, so that the elevated lock can descend, at which time the depressed lock has been raised so high and the extraneous load therof so decreased, that the pressure of equilibrium therein is less than in the elevated lock, from which time the depressed lock ascends until it is fully elevated and is brought to rest by the hydraulic stops, and the elevated lock descends until the segmental plates at the tops of the air chambers are immersed and begin to take on the extraneous load, which increases as the lock descends, and the plates are immersed to greater and greater depth, such extraneous load and the air pressure becoming maximum when the lock has descended to its lowest position. This maximum pressure acts in the elevated lock at the large bottom portion thereof, and induces therein the excess buoyancy necessary for its safe use. The main valve is then closed, and the accumulator valve opened, connecting the accumulator with the elevated lock, which can then be connected with the aqueduct. Both gates of the depressed lock are then opened, which is thereafter automatically floated to a higher position relatively to the surface of the water of the lower level, in which it floats, so as to contain the draft of water with which it should ascend.

The pneumatic lock will wholly change the conditions of canal construction. Heretofore, the range of usefulness and the location of canals have been limited by the water-supply available for feeding the locks from the summit level, and it has been necessary to maintain the water level within narrow

limits; and the large amount of water and the heavy currents necessary in locking have necessitated a constantly running supply and spill ways for the escape of such supply, when the locks were not operated. The small lift of the Leonardo locks necessitated the selection of gentle slopes for the lock sites, which, in many cases, involves soft foundations. In

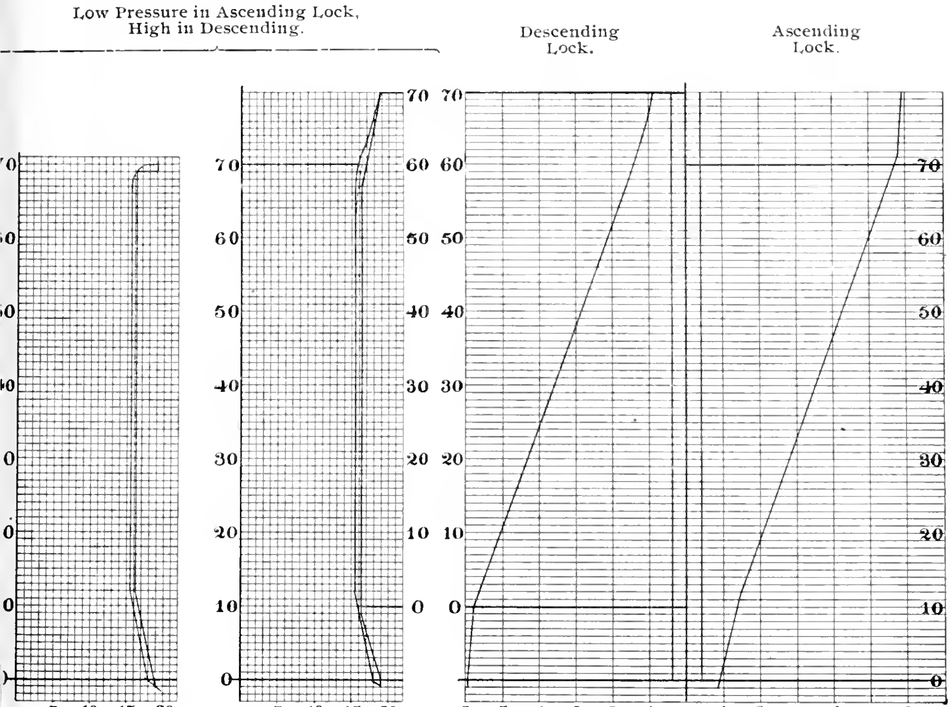
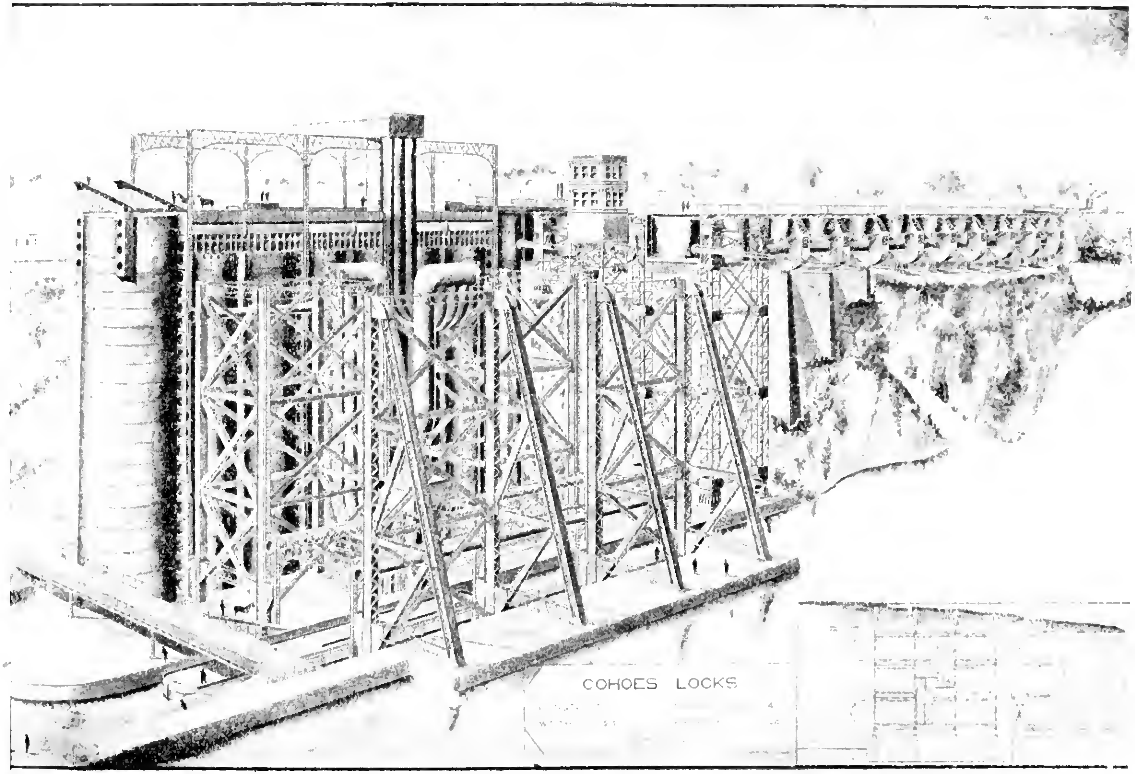


FIG. 1. FIG. 2. FIG. 3.

Vertical ordinates read stroke in feet. Abscissas read feet of water pressure, or "head" on air charge, in *Figs. 1* and *2;* and in *Fig. 3* read 100,000 of cubic feet of compressed air as distributed between the two locks during their cycle, the central ordinate indicating the position of the valve and the adjacent rectangles the conduits. In *Fig. 1* the stroke of the descending lock reads downwardly, with the motion; in *Figs. 2* and *3* all strokes read upwardly so as to show relatively coincident conditions in the two locks.

canals planned with pneumatic locks, the most economical plan will be to make the levels as long and the locks as high and few in number as possible. Guard locks and the waste of


COHOES LOCKS

water can be entirely dispensed with, and the summit level can be utilized for storage, its banks being high enough to contain the highest and its bottom low enough to give the desired draft at the lowest water, the variation being taken up at the lock. In most canals the heavy tonnage is one way, and down hill. In such cases the descending tonnage will not only operate the lock, but also lift water to the summit level. It will be seen that the first cost of canals and their demands on the water-supply are reduced to a minimum. Application of steel to the locks reduces their cost of installation, operation and maintenance as greatly as it has reduced such costs in other engineering structures. The State authorities estimate that the saving in wages at Lockport will exceed interest on the entire cost, and at Cohoes such saving will be double the interest on the cost of installation, so that building the Cohoes locks will save an actual profit. In ship canal locks the saving will be in ratio increasing with their size.

Mining and Metallurgical Section.

Special Meeting, held Wednesday, January 31, 1900.

FLUSHING OF CULM IN ANTHRACITE COAL MINES.

BY WM. GRIFFITH,
Mining Engineer.

From 15 to 20 per cent. of the coal won from the anthracite coal mines according to the methods of the past was ground so fine in the course of preparation through the breaker that it could not be used or sold, and had to be piled away as refuse. The method of doing this, and which is still largely used, is to haul the culm, as it falls from the chute, to the foot of a plane. It is then hoisted up an incline to the top of a large pile and pulled to the dumping ground by a mule, all of which process costs in the neighborhood of a cent or more per ton for the total output of the mine. The result is that at every an-

thracite mine there are to be found immense piles of refuse which are not only unsightly, but occupy considerable areas of ground which it would often be very advantageous to use for other purposes. By the wet process of preparation, though the culm is flushed into streams with water, similar objections hold.

Of late years many of these culm piles are being re-worked and the coarser portions screened out and sold for use as steam sizes, leaving the finer culm still as a waste material. Furthermore, the improvement in methods of burning fine coal has been so marked that the culm or waste produced by present methods of preparation in modern coal breakers is not much larger than the printed letter of this page. Recently, however, a new process has been originated for disposing of the waste from the mines, which has been called "flushing." By this process the culm and waste material is carried back into the mines, with water, and allowed to fill part of the abandoned portions of the underground workings. This scheme was first resorted to in 1887, by the Philadelphia and Reading Coal and Iron Company, at their Kohinoor Colliery, near the city of Shenandoah, in the Schuylkill region. Here the Mammoth Vein is about 60 feet in thickness. An immense cavity about 100 yards square had been excavated by former operators, under valuable property in the city of Shenandoah, and it was feared that in case a cave should occur it might cause great damage. In order to prevent this, the cavity was filled with culm from an adjacent culm pile, flushed in with water, through a series of bore holes which were bored for the purpose. The success of this experiment excited considerable comment throughout the anthracite region, and resulted eventually in the repetition of the process at other collieries, for various purposes.

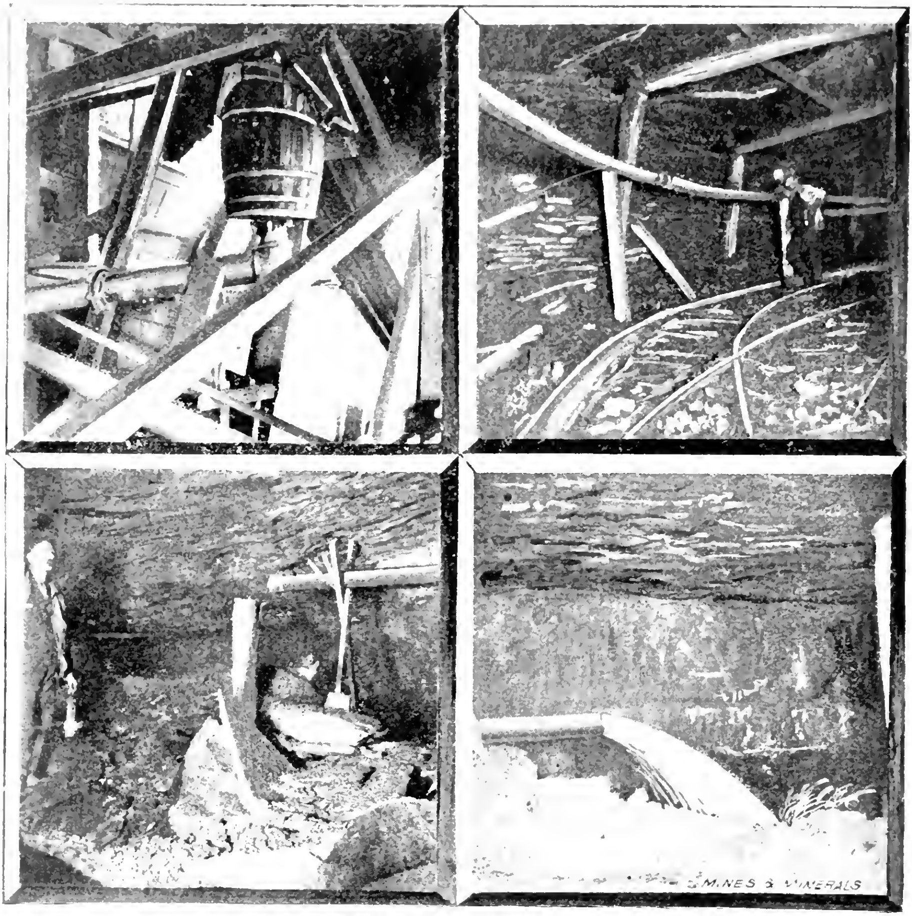
In the Northern coal field the process was first introduced in about the year 1892, at the Dodson and Black Diamond Collieries, operated by Mr. J. C. Haddock, under the superintendency of Mr. James B. Davis. Mr. Davis has since prepared a very careful and exhaustive paper upon the subject, which goes fully into the practical details of the

operation. This paper was read on January 12, 1898, at a meeting of the Anthracite Coal Operators' Association, in New York, and was subsequently published in the monthly letter of this Association, issued in February, 1898. Also in March and April issues of *Mines and Minerals*, Scranton, Pa.

This process of flushing is now in operation at many other collieries throughout the anthracite coal region, although the great majority still cling to the older method of depositing the culm on the surface.

The process is a very simple one. The culm, as it accumulates in the breaker, is carried through a system of "telegraphs" or conveyors to a hopper—usually an oil barrel. A stream of water is also conducted into the same hopper by means of a 3-inch pipe, and the culm is carried by the water through a pipe usually 4 inches in diameter, passing out of the bottom of the hopper. This pipe passes down into the mines through the shaft, or by means of a bore hole, is conducted along the gangways and up the chambers through the cross-cuts to the point where it is desired to deposit the culm. The pipe used is ordinary black wrought-iron pipe. The joints are ordinary screw joints; or more commonly a piece of 4½-inch pipe, about 8 inches long, is split on one side and placed around the pipe, being held together by two clamps. This form of joint is very simple and easy to apply. It leaks for a short time after being put on, but the crevices are soon stopped by the culm and the joint becomes tight. This pipe may be carried from the foot of the shaft either up or down the pitch. Of course, if it is carried up the pitch, more water is required to deliver the same amount of culm than is the case where the pipe is carried down the pitch or level. The culm flows freely through these pipes for long distances, and may be deposited at almost any point in the ordinary anthracite mine. The water is usually turned on about fifteen minutes before the work starts at the breaker, and is allowed to run for about fifteen minutes after work stops in the evening, in order to thoroughly clean the pipe. Occasionally stoppages occur when the pipe becomes filled with culm from one end

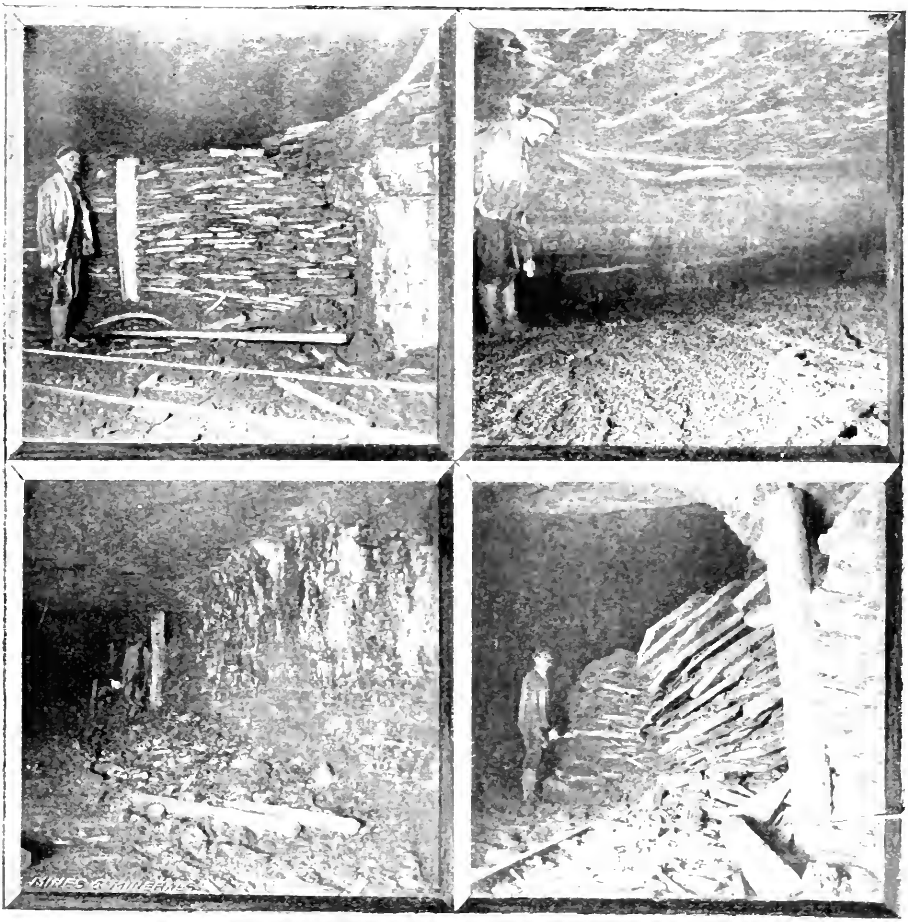
to the other, which of course requires considerable time and trouble to again clear. It is usually accomplished by breaking a joint near the foot of the shaft and allowing the pressure of the water to force the culm out of a section 100 or 200 feet in length. Connection is then made and again



broken several lengths farther on, and the water used to again clean the pipe. This process is continued until the pipe is all cleared.

The culm issuing from the pipe is discharged in the highest point of the chamber or portion of the mine desired

to be flushed, and stoppings are placed at the outlets of the chambers, near the gangways. The culm, as it is deposited from the end of the pipe, takes a very flat slope, and is carried a long distance by the water, which ultimately sinks away and filters through the deposited culm to the lower



portion of the mine, where it is pumped to the surface by the mine pumps.

The stoppings which are used are often simply board partitions placed across the end of the chamber and fitted closely; or sometimes dry walls of slate or mine rubbish are

used, a dike of culm being piled behind the wall, through which the water may filter.

When the chamber is filled to the roof the pipe is withdrawn and culm allowed to run into the next chamber, and so on the process continues until the desired area is completely filled with culm.

There are many details of the process which we do not care to enter into at this time. They will be found to be explained at length in the article previously referred to; as also the items of cost and the various advantages of the process from the cost point.

In general, it may be said that the net saving by flushing varies from $5 to $15 per day. In addition to this good showing in favor of the flushing process from the viewpoint of the expense, the advantages of the process are many, perhaps the greatest of which is the help that may be afforded the pillars by flushing culm at the time of a squeeze in a coal mine. During the past years, of course, the coal in the anthracite region has been mined largely from the upper seams, and from those from which coal could be won at the least expense, leaving the deep coals and expensive, dangerous mining for the future. During the mining of these shallow seams with thin overlying roof, the question of squeezes in the coal mines was a matter of comparatively small moment, but now that we are beginning to mine in the deeper portions of the measures, it becomes one of paramount importance. The squeezing and caving of our mines, owing to excessive weight on the pillars, has been the cause of many of the most serious and expensive mine accidents and awful disasters by which many lives have been lost, as well as much property, and will continue to be one of the great dangers of future mining in the deeper measures of the anthracite field. It has been customary in the past to leave about one-third of the coal in the ground, in the shape of pillars to support the roof, but experience now shows that it is necessary to leave a larger amount to support the roof in the deeper lying seams, because pillars composed of one-third the seam are not strong enough in all cases to sustain the weight. Besides this, in

some coal seams the pillars, after long standing, are so affected by the action of the air, heat and pressure that they splinter and chip around the margin, and pieces keep continually falling off. This process, if long continued, will often so impair the pillars of an old working, that they become too weak to support the roof, and a cave or squeeze is started. It often happens, also, that in otherwise well-conducted coal mines a limited area of the workings may be so mined that the pillar area averages much less than is intended by the management, and a weak point is made which may start to squeezing. Whatever may be the cause, a squeeze usually starts at some weak point in a mine. And inasmuch as the crushing strength of anthracite coal is about twice the weight required to start it to squeezing or cracking, a considerable time elapses from the moment that the squeeze begins until a crush finally occurs, and, as a rule, ample warning of the impending danger is given by the snapping or grunting of the pillars. As the squeeze progresses at the point of weakness, the pillars become less able to support the overlying weight; consequently, the pressure is transferred to the surrounding pillars, and the result is that the squeeze gradually progresses from the weak point to the other or stronger parts of the mine, gradually squeezing the pillars as it progresses, due to the immense leverage on the adjacent pillars which are still intact.

The method of preventing such squeezes in the past has been to build cribs or "cogs," as they are called, of logs from the floor to the roof and fill them with rock and other refuse of the mines, until a sufficient number of these cogs have been built across the line or direction of the squeeze to take the weight from the adjoining pillars and cause a crack in the roof, which immediately relieves the strain on the adjacent pillars, and the squeeze will stop. Of course, considerable settlement of the roof will occur before the cogs will take the weight, and at best this system of stopping a squeeze in the mine is very imperfect, uncertain and dangerous; whereas, if the weak point of the mine can be filled full of culm by the flushing process, it forms a

barrier which no squeeze can cross. The culm effectually fills up the cracks and crevices, all the interstices in the mine gob, and finds its way under the center of the affected parts where no man would dare to go, causing an effectual barrier capable of sustaining an immense weight; also protecting the pillars from further chipping, by excluding the air.

Now the question arises and is of considerable interest, as to how much the confined culm will be compressed by the weight of the roof, or how much it will settle. Mr. Davis ascertained by experiment that a cubic foot of anthracite coal ground to culm would be flushed into a space of nearly $1\frac{1}{2}$ cubic feet. Therefore it was impossible to compress the culm more than one-third, because it would then occupy the same space as the solid coal. In order to determine the compressibility of culm under these conditions, we have recently made a few experiments in this line. The first and second experiments were with wet culm; the third with dry culm. A section of 4-inch wrought-iron pipe $9\frac{1}{4}$ inches long was flushed full of culm and after the water had drained off, was placed in a hydraulic press and the pressure required to compress the culm noted. The same was done in the second experiment, using a pipe 3 inches internal diameter and $15\frac{1}{4}$ inches long. In the third test a cylinder of cast iron $3\frac{3}{8}$ inches diameter and $13\frac{7}{8}$ inches long was flushed full of culm and placed on top of a nest of boilers for about a week until it became thoroughly dry. The results of these tests are shown in the following tables, indicating tests Nos. 1, 2 and 3 in triple columns. It will be noted that, other things being equal, dry culm will withstand two or three times the weight of wet culm. It requires a long time for culm to dry after being flushed into the mine. It is not often, therefore, that dry culm could be depended upon to withstand the weight of a mine squeeze. However, when it does become dry it is so firmly compacted that gangways may be driven through it having vertical walls of culm on either side which show only a slight tendency to caving.

While these tests are very crude and the results are

rather varied and altogether unsatisfactory, still, so far as our knowledge goes, they are the only tests ever made in this particular line and we trust are only the beginning of more extended ones to be carried forward under more exact methods and more favorable conditions. They are introduced here because they will serve to at least give a better idea of the extent to which culm may be depended upon to hold the roof of a caving mine, which has heretofore been a matter of mere conjecture by engineers of the coal fields.

Compression in Inches.	Weight in Tons.			Tons. Weight Per Square Inch.			Per Cent. of Compression.			Remarks
	1	2	3	1	2	3	1	2	3	
½	—	2	6	—	·29	·67	—	3·28	3·7	
1	—	4	9	—	·57	1·0	—	6·56	7·44	
1½	7	6	14	0·56	·85	1·57	16·	9·83	11·16	
2	13	8	23	1·04	1·14	2·57	21·6	13·12	14·88	
2½	34	12	35	2·72	1·71	4·0	27·0	16·3	18·6	Test No. 1. Pipe began to expand.
2¾	34	—	48	—	—	5·4	—	—	20·46	Test No. 1. Pipe burst
3	—	19	56	—	2·71	6·26	—	19·67	22·34	
3¼	—	—	61	—	—	6·82	—	—	24·18	
3⅜	—	26	—	—	3·71	—	—	22·14	—	
3½	—	—	70	—	—	7·83	—	—	26·04	
3⅞	—	38	—	—	5·43	—	—	25·42	—	Pipe burst.

Test No. 1. 4-inch gas pipe 9¼ inches deep, flushed full of culm and drained.
" " 2. 3 " " " 15¼ " " " " " " " "
" " 3. 3⅜ " cast cylinder 13$\frac{7}{16}$ " " " " " " "thoroughly dried

We note by test No. 2 that to produce a compression of 10 per cent. would require about $\frac{9}{10}$ of a ton in weight per square inch. Therefore, in a 5-foot seam of coal, if we assume the superincumbent strata to weigh about 145 pounds to the cubic foot, a pressure of about $\frac{9}{10}$ of a ton per square inch would be produced by a column of sandstone 1,800 feet high. In a 5-foot seam which had been completely flushed with culm the compression caused by this weight would be about $\frac{1}{2}$ foot, an enormous resisting power.

From the experience of the past, as well as tests which

we have recently made, we know that the pillars of a coal mine will begin to squeeze when the pressure upon them amounts to from 400 to 4,000 pounds per square inch, depending upon the thickness of the bed, quality and firmness of the coal and the conditions under which it is mined. Therefore, for example, to show the utility of flushing, if we assume mining at 500 feet depth in a bed in which we know by test that the weakest bench of coal will begin squeezing at 1,500 pounds per square inch, if two-thirds of the coal in such a mine be exhausted, we know we have a weight on the pillars which is liable to start a squeeze at any moment, particularly if in any part of the workings the pillars average less than one-third the whole, or the pillars of the seam are subject to much chipping. Therefore, by examination of the mine and the maps, the engineers may select the weak points and flush them with culm, knowing that if a squeeze should start, the roof could settle only about 3 to 8 per cent. of the thickness of the bed; or, if the culm were dry, only about 2 per cent., after which the culm would take the weight and stop the squeeze. From which it may readily be seen that culm flushed into the mines by this process becomes an ample and positive safeguard against the crushing of the mine, if properly done. Of course, in case of robbing or remining the pillars after flushing, the settlement would be much greater than above stated, unless the space formerly occupied by the pillars be reflushed.

The advantage also of culm as a preventive of mine fires must be conceded. It has been supposed that the culm thus deposited would be subject to spontaneous combustion, as is so often the case with culm piled on the surface. Experience, however, shows that spontaneous combustion is not liable to occur under these conditions. Many tests have been made by digging through the culm to the bottom rock, but in nearly all cases no sign of heat or fire has been discovered, and there is no case on record, so far as we are informed, of the culm thus deposited taking fire spontaneously.

We know of no attempt to use a mixture of culm with water for the purpose of drowning a mine fire, but it would

seem that it might readily be used for this purpose, since by placing the proper stoppings around the fire, as is usually done, for excluding the air, that water and culm could be flushed in through borings from the surface until the space was completely filled with wet culm. This method would effectually exclude the air, and in all probability stop the fire, particularly if water was kept running in the bore hole, so that it could seep through the culm, in order to keep it wet.*

There are many other advantages which might be named in favor of this process, but we have not time to consider them here. There is one other point, however.

The question will of course arise as to how much additional coal may be mined by first flushing the old workings with culm and then extracting the pillars. This may be safely done and is a very advantageous way of robbing pillars where the surface contains valuable property which cannot be disturbed. The quantity of coal which may thus be recovered in addition to that obtained by the first mining over is a question which is entirely controlled by the thousand and one conditions which obtain at each colliery. In some cases little coal, in others much; perhaps 20 per cent. or more may be saved, providing the mine is worked and portions flushed with the view of remining it. This process has been considered so advantageous that at some particular mines in our Northern coal field they are now taking the culm from the old banks without rescreening to save the small sizes, passing it through rollers to grind up the large particles, and flushing it into the mine for the purpose of filling up, with the idea of remining the pillars or preventing a squeeze at particular parts of the mine, and so on.

It is quite likely that this process will become more and more used as the coal approaches exhaustion, and especially will this be the case in connection with the deep mines of the future. So that this question of the flushing of culm

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* Since above was written instances have been recorded where culm has been thus used successfully for stopping mine fires. See *Mines and Minerals*, February, 1900.

in the mines may eventually be expanded to the larger question as to whether or not it may be advantageous, when facilities warrant, to flush sand, loam and other material from the surface into the mines, for the same purpose. In our opinion it is quite likely that we may ere long see the time when this may be done to advantage in particular cases.

ELECTRICAL SECTION.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

The commercial incandescent lamp is now in its twentieth year. In this short period it has grown from a weakling to a giant of industry. The value of the manufacturing lamp business of the United States alone aggregates over $2,000,000, with a total production of between 15,000,000 and 20,000,000 lamps per year, and European factories will swell this total output to over 25,000,000 per year.

Assuming the value of a lamp at 20 cents, we have an annual expenditure of between $4,500,000 and $5,000,000, paid for this one detail of electric lighting—certainly a significant index of the great value of the electric industry.

Although an apparently small detail of electric lighting, the incandescent lamp is the most important part of the system.

Some one has well said that the incandescent lamp is the very soul, the essence of electric lighting, and it is an evident fact that electric lighting cannot improve any faster than the art of lamp manufacture permits.

Electric lighting waited for the production by Edison of a successful incandescent lamp. The improvements in electric machinery and methods of distribution, the refined results obtainable to-day, have caused more dependence than ever to be placed upon the incandescent lamp, and have accentuated the need and the importance of the most superior quality of lamp to secure the best results.

The selling price of good lamps has been brought down from $1 apiece to an average of 18 cents. This immense reduction alone would be a great achievement were it not rendered still greater by the great improvement in quality of the product. Measured by the standard of the best lamp of to-day, sold for an average price of 18 cents, the lamps that sold formerly for $1 would be very costly as a gift to any central station.

As we glance back over the field of development we find many features of interest, and I propose this evening to describe a few of the more important and interesting features in detail, such, for example, as:

The improvements in lamp manufacture.

The advance in quality and change in types and standards of lamps, and the improvements in method of supply.

The widened field of lamp use, and the production of special types and forms for special service.

The advance in methods of lamp testing.

The better understanding on the part of purchasers of the essentials of a lamp and of its correct use.

IMPROVEMENTS IN LAMP MANUFACTURE.

The production of a lamp involves many operations, but the real essentials are four in number: Making the filament; treating or "flashing" the filament; joining the filament to the conducting connections; and exhausting the lamp. The remaining processes, such as sealing in bulbs, capping, etc., are mechanical and simple.

The early struggles with platinum, silk, tamadine and various natural fibers, down to the selection by Edison of Japanese bamboo, are well known. The old bamboo filament had many disadvantages. The natural bamboo could not always be obtained of uniform density and character. The filaments were limited in length. The production of the filament by the cutting and shaving of the bamboo sticks involved a large amount of labor and waste of material.

We now beat nature at her own game. We make a fiber any length, size or shape, and we make it uniform. We mould cotton into a filament as the brickmaker makes his bricks, by making a solution, moulding (*i. e.*, squirting it)

into desired shape, then drying out the solvent and baking it.

With the old bamboo filament the Edison factory, for a production of 20,000 lamps per day, employed 350 people cutting fiber. With twice this production of lamps, *i. e.*, 40,000 per day, but twenty-five people are necessary to produce the squirted filaments. With the bamboo over 90 per cent. of the crude material was wasted; with the squirt filament over 95 per cent. is utilized.

The treatment or flashing of filaments has always been rightly considered a most marked improvement in lamp manufacture.

As is well known, all lamp filaments, after carbonization, are subjected to a treating or depositing process. This deposition is accomplished by burning the filament at high incandescence in a chamber in the presence of gasoline vapor. The white-hot filament decomposes the gasoline vapor, depositing a surface coating of graphitic carbon over the filament. It is of interest to note that the reasons for its adoption no longer apply, and that it is retained to-day for other purposes. The early filaments were all untreated.

It was impossible then to make filaments uniform and free from uneven sections or points, and it was very difficult to cut the filaments to a given resistance. The treating process was devised to overcome these difficulties. By filling in the uneven points with the carbon deposit the filament was rendered uniform. The gradual increase of diameter through the carbon deposit allowed the resistance to be decreased to any fixed amount, readily and accurately.

The present cellulose filaments are made both uniform and of the desired resistance, so that treatment is not now necessary for these results. Why, then, is treatment still continued? Because it gives a hard, dense surface coating of graphitic carbon, which is more durable than the filament base of amorphous carbon, and also because it effects an increase in the emissivity of the filament. Consider the case of two filaments, one treated, the other untreated, and both consuming the same current. The surface coating of the treated carbon acts to retain the heat, which is radiated more rapidly from the untreated surface of the other. This re-

sults in raising the temperature of the treated filament above the untreated, and giving a higher candle-power. This means an increase in efficiency, since it is evident that to give the same candle-power less power would be required by the treated filament.

The early methods of treatment required that a filament be treated by steps, *i. e.*, treat a few seconds, then take out and measure, and so on until the desired resistance was obtained. How crude this seems compared to the present automatic Wheatstone bridge arrangement, which instantly arrests treatment when the desired resistance is reached. This arrangement alone has reduced the employés to one-quarter of the number formerly necessary.

The progress in the art of joining filament to connections is clearly shown from an examination of old and present lamps. We trace it through from the early bolt and nut clamp of Maxim, the electro-plated joint of Edison, down to the modern paste and deposited joints—a marked advance toward simplicity and lessened cost.

In the exhaustion of lamps, manufacturing methods were for a long time slow of improvement. What was needed was a rapid and effective method of pumping that would admit of lamps being exhausted singly. With mercury pumps to secure full productive capacity, it was necessary to exhaust lamps in batches of 50 to 100 at a time, so that lamps could not receive the individual attention necessary to secure best results. This same difficulty existed for a long time with mechanical pumps, and, besides, mechanical pumps could not unaided produce the degree of exhaustion desired. The introduction of what is known as the "chemical" process of exhaustion marked an advance in lamp manufacture second only to the introduction of the cellulose filament. In this process rapidity is obtained by means of a special mechanical pump, permitting the exhaustion of lamps one by one. The refinement of the vacuum is accomplished by a special chemical process. We cannot pump all the gases out of the bulb, so we set a thief to catch a thief. By introducing a gas capable of combining with the residual gases remaining in bulb we render these gases innocuous and secure a vacuum of perfect insulating properties. It is this

process that has assisted more than any other one thing in the production of a successful 200–250-volt lamp, concerning which I have something to say later.

The improvement in methods since the early days is strikingly shown in the reduction in time of exhaustion of a lamp fróm five hours to one minute.

In photometric work the use of the revolving stand for the lamps in place of the fixed stand has greatly improved the accuracy and certainty of measurement. We now obtain the true mean horizontal candle-power of each lamp. Lamps are now readily measured to tenths of a candle, and the duplication of readings to within one-quarter of a volt by different operators made a regular result.

Generally speaking, methods and details of execution of the various processes have been carried to a high degree of perfection. By the subdivision of processes, limiting each distinct operation to one set of operators, by constant systematic and rigid inspection and testing following each operation, manufacturing results have been made far more exact; elimination of defects has been carried to a remarkable degree, and the precision of manufacture of simple mechanical products approximated to very closely.

IMPROVEMENTS IN QUALITY.

The art of lamp manufacture is not an exact one. The same methods will not always yield the same results. Slight or insignificant changes in processes produce most unexpected consequences and render it specially difficult to locate and remedy the cause of defects. The path from cause to effect is most undefined and undiscernible. Starting any improvement in a lamp, it requires a month or six weeks of testing by burning the lamps to ascertain the effects. All the processes must be exact, and the test along rigid lines, as otherwise the effect of the improvement may be masked or even discounted by other effects. Trial must be made not of one lamp, but of a large number, so as to secure the true average results, and avoid being misled by exceptional performances. In general, results are obtained only by a series of approximations.

In addition, the varieties of lamps required are surpris-

ingly large, so that to the inexactness of the art is added a great complexity of product. Taking ordinary multiple lighting lamps for central station service, and omitting all specialties, we have at least ten thousand varieties of lamps in regular demand, and if we consider all the special types of lamps, miniature and battery lamps, etc., the actual varieties number over a hundred thousand.

Still further we must note that, of any lot of lamps under manufacture, not over one-third will come out at the voltage aimed for. This means, for example, that to produce 10,000 lamps for any given exact voltage, it is necessary to make between 30,000 and 40,000 lamps, and then select from these the 10,000 lamps desired.

These several considerations may show something of the difficulties that beset the lamp manufacturer and serve to arouse our admiration of the advancement made in his art.

The most notable advance is in the matter of voltage. The early lamps were limited to 110 volts, and on alternating circuits to 50 volts. Although the 110 volt range was extended to 120 volts, lamps of these voltages were very unstable in candle-power and uncertain as to life, except at very low efficiencies, and the 50-volt lamp was the only lamp that could give fairly satisfactory results at anything better than 4 watts to the candle.

Improvements have materially changed this order of affairs. The quality of 100 to 125-volt lamps has been advanced very close to the naturally better quality of the 50-volt lamp, so that the large difference in results and performance between 50 and 100-volt types no longer exist. The 50-volt lamp was formerly twice as good as the 100-volt lamp, while at present it is but slightly more than one-quarter better. This, with the better distribution afforded from 100-volt secondaries, and better regulation obtainable with larger transformers, is rapidly causing the displacement of 50-volt lamps. In a few years the 50-volt lamp will practically be obsolete.

The tendency is all the other way, as the limits of voltage of practical incandescent lamps have been extended to 200 and to 250 volts. These 200–250-volt lamps have been very successful. Over 400,000 of them are now annually supplied

to consumers, and their use is being rapidly extended. The limitation to the use of 200-volt lamps is their low efficiency, which is 4 watts per candle or lower. At this efficiency they compare with 100–125-volt lamps of 3·1 watts per candle, giving a useful life about one-third better. In fact, they stand about halfway in results given between the 3·1-watt and 3·5-watt 100–125-volt lamps. This difference of $\frac{7}{10}$ watt per candle, or 22 per cent. more power than the 100-volt lamp for same results, weighs against the lamp, as it means reduced light capacity of dynamos and engines and increased consumption of fuel as well. The better distributing advantages of the 200-volt system have not, therefore, been sufficient to cause a change as yet in the large direct-current central stations.

It is certainly safe to expect that, with the increased demand for these high-voltage lamps (due to the economies of distribution of the 200-volt system), concentrated skill and attention will improve their quality, and bring them nearer to the naturally better results of 100-volt lamps. This would be but repeating the history of the 50-volt versus the 100-volt lamp.

The decision of what voltage to adopt for a new installation—100 or 200—is a matter of proper engineering. As far as the incandescent lamp is concerned, the choice of the systems, as between 100 and 200 volts, follows the simple law that interest on cost of copper saved by 200–250-volt system over the 100–125-volt system must be equal to or greater than the interest and depreciation on the cost of the extra capacity of machinery and copper, plus the annual cost of extra power required by 200-volt lamps over the corresponding 100-volt lamps. It has been shown by the writer (*Electrical World*, October 2, 1897) that these conditions are independent of the number of lamps and depend only on the square of the average distance from station to lamps.

Numerous inquiries are made as to the prospects of obtaining a higher efficiency lamp of this type. The 4-watt lamp is so good, it is said, why is not a 3½-watt lamp possible?

A $3\frac{1}{2}$-watt 200 to 250-volt lamp is practicable. A number of such lamps have been made and sent abroad and used in special installations in this country, where they have given good results. The conditions are not ripe as yet, however, for the marketing of such a lamp. The average 200-volt station has not very close regulation, and few such stations appreciate the correct principles of lamp use. They compel their customers to buy and supply the lamps used, and as they generally sell their current by contract and not by meter, the change to the higher efficiency $3\frac{1}{2}$-watt lamp would be a disadvantage to the consumer in shortening both the useful and actual life of his lamps. He would most naturally complain and condemn the lamp. To introduce a lamp under these conditions is most undesirable. Besides there are but comparatively few installations at voltages other than 220. Since all lamps cannot be made exactly to voltage, this compels the shipment of lamps of quite a range of voltage, operating directly against good life service of a higher economy lamp, as close rating in voltage is a necessity therefor. What is needed is a number of stations operating at different voltages with close regulation—supplying current on meter with free lamp renewals. A higher economy 200-volt lamp might then be introduced and tried with something like fair results.

These conditions will gradually grow and the $3\frac{1}{2}$-watt lamp with them. In the meantime we may look for the introduction of lamps between 4 and $3\frac{1}{2}$ watts economy. One large station has already arranged for a supply of 3·8-watt lamps on its 200-volt circuit, and it is possible that this economy will supplant the 4-watt type.

In the economy or efficiency of 100–125-volt lamps the advance has been made from 5 and 6 watts to 3 watts per candle. Surprise is frequently expressed that a higher economy than 3 watts has not been made and put in service. This surprise is natural, but shows a lack of understanding of the meaning of efficiency. It is true that the so-called 3·1-watt lamp has been on the market for some years, but what was the early 3·1-watt lamp? It was a lamp so made as to consume 3·1 watts per candle of light at the start. In a few

hours it became a $3\frac{1}{2}$-watt lamp and ended a short and inglorious life at below 5 watts to the candle. Now a $2\frac{1}{2}$-watt lamp can be obtained to-day that will give as good results as these early 3·1-watt lamps. Fortunately, however, customers have grown to appreciate good maintenance of candle-power, and have learned that it is the average efficiency of a lamp and not its initial efficiency which is the proper measure. By the test of average efficiency for the shortest period of life acceptable to-day—400 hours—there is as yet no full 3-watt lamp, the average being for the best lamps to-day about $3\frac{1}{4}$ watts per candle.

It is by the comparison of average efficiencies that we can best note the improvement in lamp quality. The greatest advance has been along this line, *i. e.*, the increase in average efficiency. The early 3·1-watt lamps had an average efficiency of about 3·8 watts per candle, and even below 4 watts, if we reckon results for the long period lamps were then continued in service. To change from 3·8 to $3\frac{1}{4}$ watts per candle marks, therefore, a most decided progress. This has been accomplished not only by improvements in manufacture, but also by the education of lighting companies to accept a shorter period of service from their lamps, and renew them frequently instead of permitting them to burn until broken.

Close and uniform rating is one of the chief essentials for a lamp, and a distinct advance has been effected in this respect. Early conditions with extreme voltage variation and the absence of meters rendered it perhaps redundant to have close candle-power and watt limits. This is a noteworthy instance where refinement of service conditions has made refinement of product a necessity. Again the early installations were all too largely established at some so-called standard voltage, 52, 104 and 110. The well-known inexactness of lamp manufacture as to voltage was far worse then than now, so that to ship his entire product the manufacturer naturally gave out quite an assortment of voltages. Since that time the importance of distributing installations at various voltages has been preached and practised, and the overcrowding of voltages like 104 and 110 somewhat relieved.

The adoption of a common standard of candle-power among manufacturers has likewise assisted. The time when each manufacturer had a candle-power standard of his own has passed. The leading American companies are to-day rating their lamps by the English parliamentary standard, taking the mean horizontal candle-power of each lamp when rotated at about 180 revolutions per minute.

The leading makers now photometer each and every lamp, and the practice of photometering a few and picking out the remainder by the eye is past, or continued only by the small and incompetent factories. The result is that lamps are to-day regularly supplied by the reliable manufacturer tested to the quarter of a volt, no lamp varying more than 1 candle above or below its rating, nor more than 6 per cent. above or below its rated wattage when tested at marked voltage.

This close and uniform rating has a most marked effect in improvement of the service the lamps give. With close candle-power and total wattage rating, their ratio, the watts per candle, is fixed exact. This means that all the filaments burn at exactly the same temperature and strain. It is quite evident that evenness of this temperature or strain will materially increase evenness of results in the life and maintained candle-power performance.

Let me refer again to the subject of so-called standard voltages. Although, as stated, there has been some relief from overcrowding these voltages, conditions are as yet far from perfect. Generally speaking, customers who remain at such voltages as 104 or 110 or 220 will invariably get the poorest lamps of whatever make they may purchase. This is a fact that cannot be too generally known. There are more than three times as many 110-volt lamps used to-day than are made. This means that the average customer who orders 110-volt lamps gets lamps marked 110, but really of some other voltage (either 107, 108, 109, 111, 112 or 113). There is no virtue in 104, 110 or 220, and the wise central station manager is he who changes his voltage to some special point, as, for example, 107 and 108, or 113 and 114, 117 and 118, 122 and 123, 208, 212, 230, 240, etc. Such

changes can be and have been made with comparative ease even on the largest installations.

The standard lamp of this country is the 16 candle-power lamp—in Europe the 8. In the last two or three years the demand for lamps of lower candle-power, 10, 8, 6 and even 4, has grown very large. This has been due to enforced competition for residence lighting, to the adoption of meters and to sign and decorative lighting. As a general principle in lighting, a number of small units can be distributed to give a better illuminating effect than an equivalent candle-power in larger, and, therefore, fewer units. Thus, sixteen 8 candle-power lamps distributed will give better results than eight 16 candle-power lamps. For many locations a 16 candle-power lamp is too large a unit. Electric light must compete with gas, which is quite largely used turned down. These are some among many reasons why the lower candle-power lamps, such as the 8 candle-power, should be more largely used and perhaps become the standard in place of the 16. The difficulty is that an 8 candle-power lamp cannot be made which at the same efficiency will give results equal in either life or maintained candle-power performance to the 16 candle-power. This is due to the naturally thinner and more delicate 8 candle-power filament. This results in the use of 8 candle-power lamps of lower economies than that of the 16 candle-power in use, unless shorter life and reduced candle-power performance are to be accepted. The alternative of shorter life could be adopted to advantage by many central stations who to-day retain their 16 candle-power lamps too long in service.

The quality of the 8 candle-power lamps, formerly very poor, has, however, in the last two years been materially advanced, so that it is not much below 100 hours short of the 16 candle-power lamp in useful life. This is under perfect voltage conditions. As in service such conditions are but seldom realized, 8 candle-power lamps will not appear to quite such advantage.

In physical respects the modern lamp appears to most marked advantage in comparison with the early types. The bulbs then blown free-hand, of varying sizes and

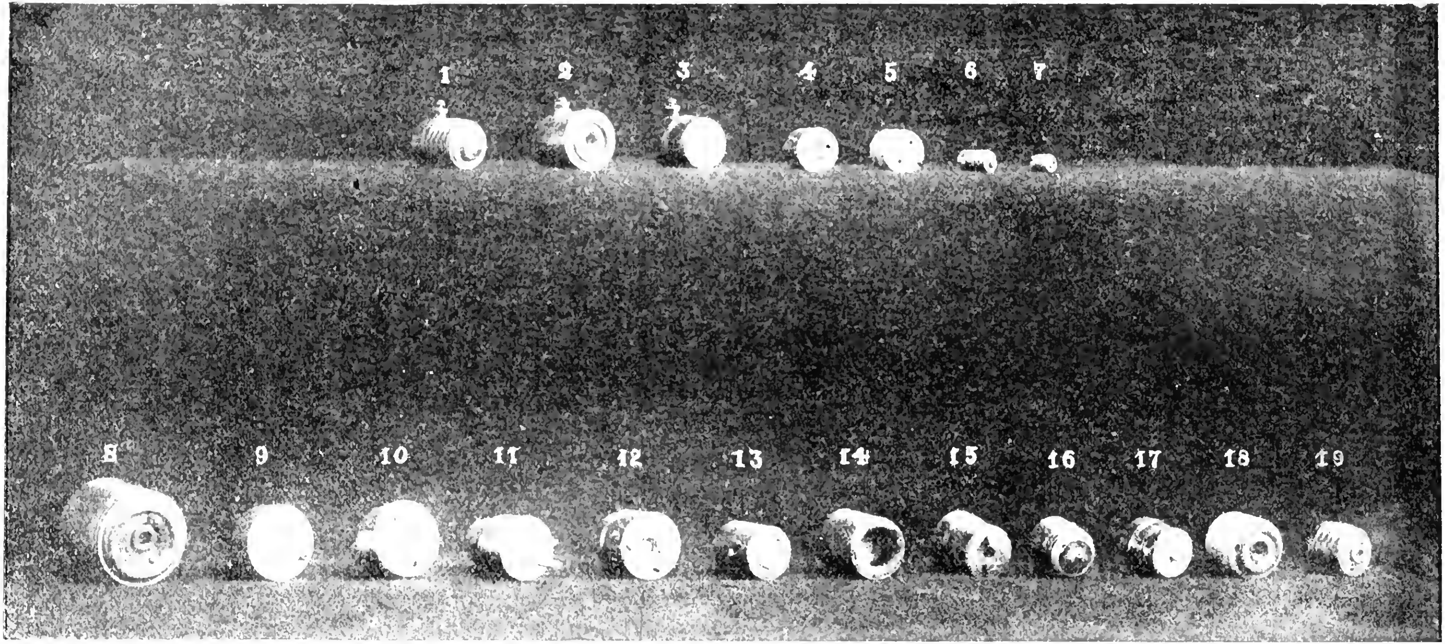


PLATE I.—Types of the different styles of lamp bases.

1—Base Edison night lamp.
2—Base Thomson-Houston night lamp.
3—Base Westinghouse night lamp.
4—Edison Swan base (brass).
5—Edison Swan base (porcelain).
6—Base candelabra lamp.
7—Base miniature lamp.
8—Base series lamp (bottom cut out).
9—Bernstein base.
10—Schaeffer base.
11—Fort Wayne Jenny base.
12—Loomis base.
13—Hawkeye base.
14—Mather or Perkins base.
15—Brush Swan base.
16—United States base.
17—Westinghouse base.
18—Thomson-Houston base (porcelain)
19—Edison base.

shapes, are now replaced by the moulded bulb of exact size to the die. The long concave neck has given place to the short-neck straight-sided bulb of less obtrusive and more practical character.

The filaments have been symmetrically shaped, giving an artistic effect and increasing the spherical candle-power (with the same mean horizontal). The filaments are anchored or so supported that there is no drooping. The inside parts are all accurately gauged and placed, so that each lamp is the exact counterpart of any other in respect to all its details.

In early days every manufacturer of a new system had to have a special socket and lamp base. There were no less than thirteen different types of bases in this country alone, and in Europe about as many more varieties. This naturally multiplied the types of lamps very greatly, and was a great burden to both manufacturer and customer. Simplification has progressed so far already in this matter that there are to-day in this country practically only three bases, the Edison, Thomson-Houston and Westinghouse. The tendency is strongly towards a still further reduction to one, *i. e.*, the Edison. This is a pure case of survival of the fittest. The Westinghouse base and socket have, as is well known, the grave faults of poor and uncertain contacts, which are aggravated by use. The Thomson-Houston, while perhaps a good socket, is one of the most troublesome of bases. The screwing of a Thomson-Houston base in its socket acts to tear it apart (the reverse of the Edison, where the result is a binding action holding the parts together); the contacts are very close together, and are liable to arcing and short-circuiting. The Thomson-Houston base is also complex and expensive. It has three or four parts to two for the Edison, and costs about 1 cent a piece more. On this account there is an extra charge of 1 cent per lamp on all Thomson-Houston base lamps, and this is operating effectually and gradually to render the Thomson-Houston base obsolete. This change is helped by an adapter, furnished by the General Electric Company, which, by simply screwing in the socket, changes it from a Thomson-Houston to the Edison type.

This change to one standard base will require some time, however, as there are still a large number of both Westinghouse and Thomson-Houston in use, and the change of the Westinghouse requiring a complete replacement of sockets is costly and troublesome. Roughly estimated, the proportion of the different sockets in use in the United States is as follows:

	Per Cent.
Edison	55
Thomson-Houston	25
Westinghouse	15
All other types	5

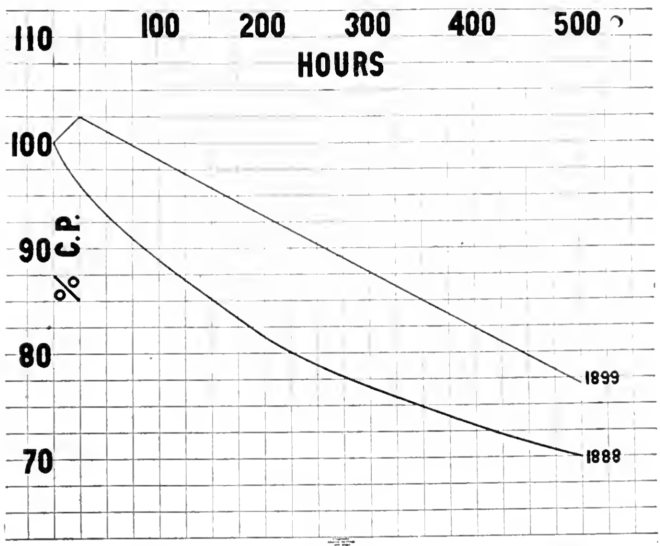


FIG. 1.—Curves showing ten years' improvement in candle-power performance of 3·1-watt incandescent lamps.

The only real objection to the Edison base was the live contact exposed by the portion of the shell part of base extending outside of socket. This has been corrected by shortening the shell, so that socket entirely covers base. The use of porcelain marks the greatest improvement in bases—the Thomson-Houston base is now made entirely of porcelain with metal contacts.

The improvement in average efficiency to which I have

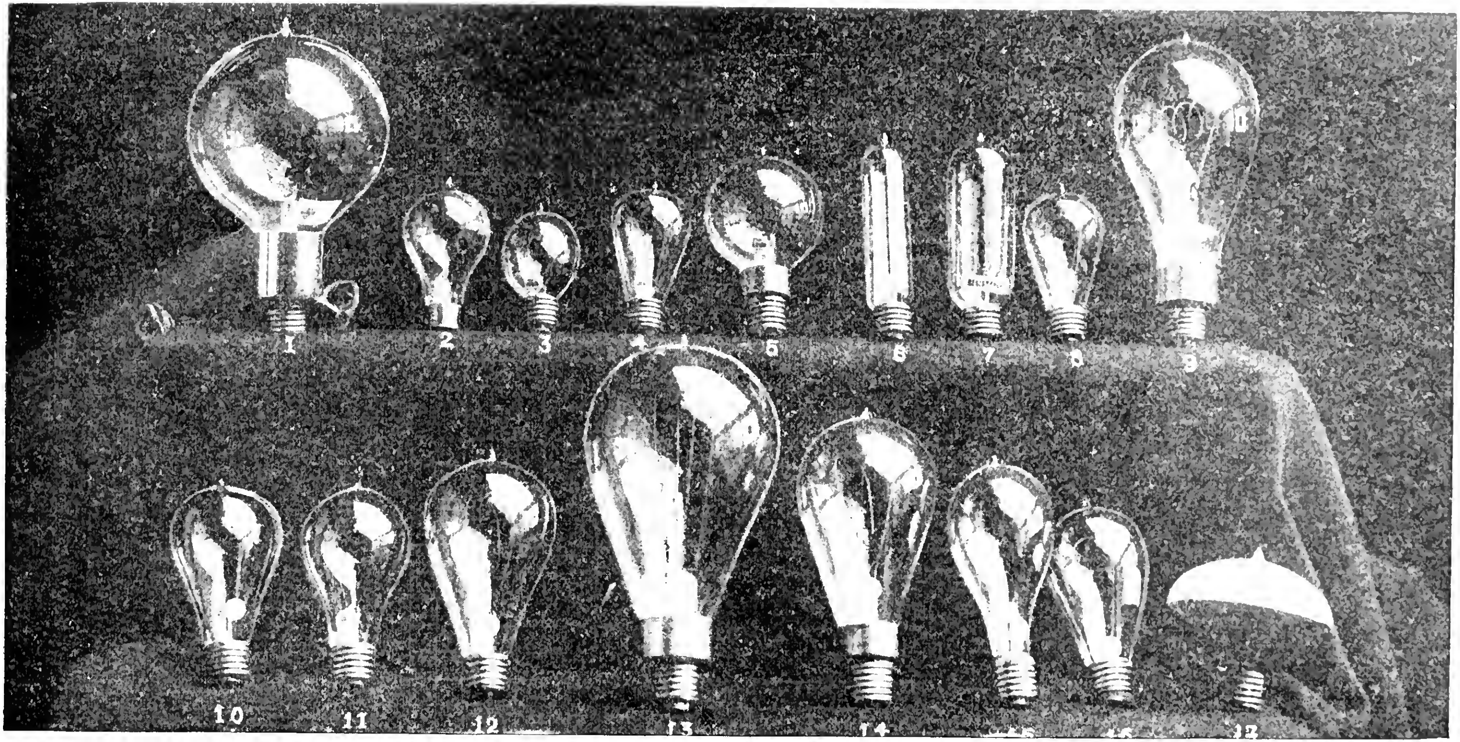


PLATE II.—Types of standard and special multiple lighting lamps.

1—Lamp for buoy lighting.
2—European lamp.
3—Round bulb lamp.
4—10 c. p. 100-125-volt lamp.
5—Stereopticon lamp, 50 c. p.
6 Tubular lamp.
7—Resistance lamp.
8—4 c. p. 100-125-volt lamp.
9 Diving lamp.
10—Standard 16 c. p. 100-125-volt lamp.
11—Standard 16 c. p. U. S. N. cruiser lamp, 80-volt.
12 Standard 32 c. p. 100-125 volt lamp.
13—Standard 100 c. p. lamp.
14 Standard 50 c. p. 100-125 volt lamp.
15 Old style lamp. Free blown bulb.
16 10 and 16 c. p. 50-volt lamp.
17 Reflector lamp.

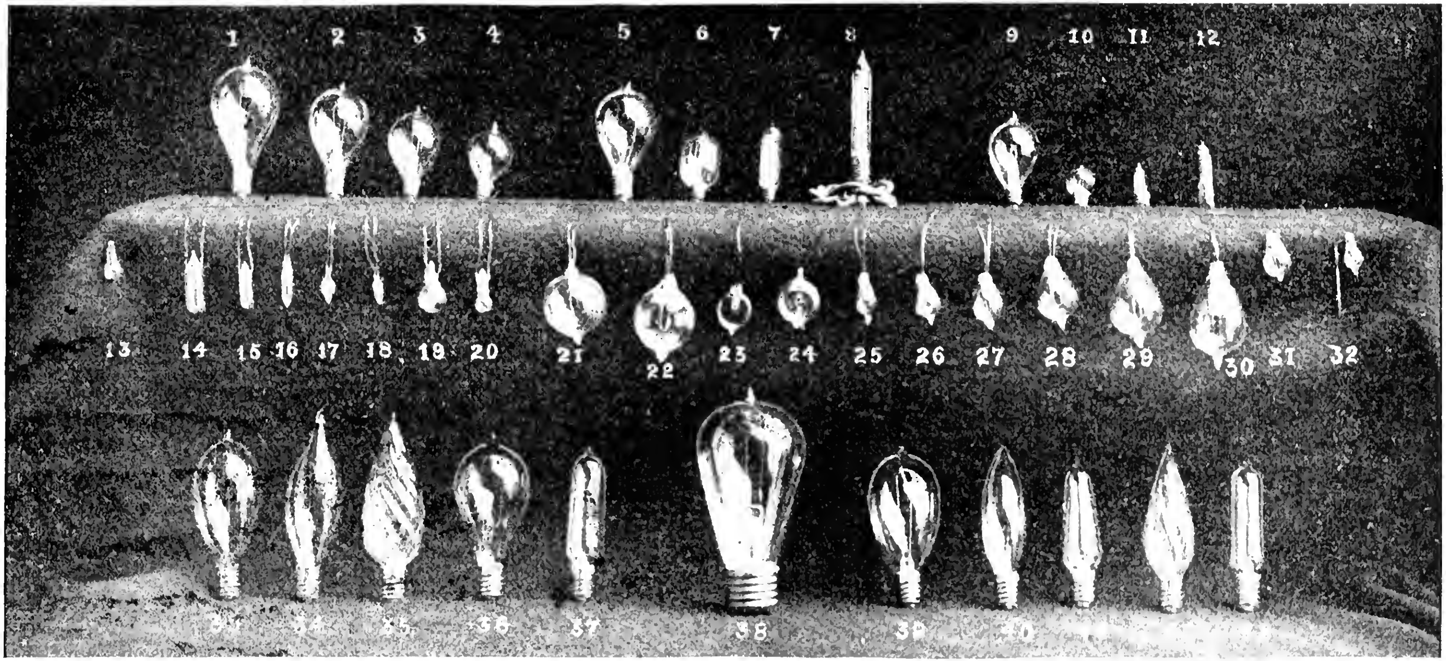


PLATE III.—Types of miniature lamps.

SPECIAL SERIES LAMPS.

1—8 c. p.
2—5 c. p.
3—3 c. p.
4—1 c. p.

U. S. N. LAMPS.

5—Binnacle lamp.
6—Instrument lamp.
7—Instrument lamp.
8—Torpedo lamp.
9—Kinetoscope lamp.
10—Bicycle lamp.
11—Telephone lamp.
12—Telephone lamp.
13—Watch charm lamp.

DENTAL LAMPS.

14—
15—
16—
17—Pea lamp.
18—Surgical lamp.

MICROSCOPE LAMPS.

19
29
21—4 c. p. spherical lamp.

FLAT LAMPS.

22—4 c. p.
23—1 c. p.
24—Miner's lamp.

BATTERY LAMPS.

25—½ c. p.
26—1 c. p.
27—2 c. p.
28—3 c. p.
29—4 c. p.
30—6 c. p.
31—Theatrical.
32—Stick pin lamp.

MULTIPLE CANDELABRA LAMPS.

33—Style A.
34—Style B.
35—Style D.
36—Style E.
37—Style F.
38—Battery lamps for steam railway carriage lighting.

SERIES CANDELABRA LAMPS.

39—Style A.
40—Style B.
41—Style C.
42—Style D.
43—Style E.

referred concerns the candle-power performance. Such a notable advance has been made in this respect, however, that it will be of interest to speak of it again in another way.

In diagram, *Fig. 1*, we have two curves—the lower one shows the candle-power performance by hours of burning for the early 3·1-watt lamps, and the upper one the present lamp of same make. The early lamp reaches 80 per cent. of 16 candle-power, the comparison basis, at 200 hours, and the present lamp at 450 hours.

Such lamps as give a result like these early ones no station could afford to-day to use, at less than half the price of the present best ones.

A word or two about the improved methods of supply. Lamps are now purchased by all large users on what is known as the future delivery system. On this plan the customer places his order for his year needs, specified as to types desired, with the manufacturer, and lamps are shipped to him thereon during the year as he needs them. This system has proved of inestimable value to both manufacturer and customer. It permits the manufacturer to run his factory uniformly through the year, avoiding the old conditions of heavy rush production in the fall and winter and the reduced output of summer. It allows the accumulation of the requisite stocks for prompt shipments during the rush season. It guides the manufacturer as to the classes and types of lamps desired and the number of each, and thus enables him to avoid producing dead stock. In early days the dead stock accumulated through lack of knowledge of requirements was tremendous. Many thousands of lamps that could not be sold had to be annually broken up.

The economies of this future delivery system secure the customer a special price. It is not too much to say that the future delivery system is the mainstay of the lamp business to-day. It would be impossible to supply the high-grade closely-rated product sold to-day at the present low prices without future delivery orders from the consumers.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held January 16, 1900.

RACEMISM.

BY ROBERT HART BRADBURY.

I. HISTORICAL.

In 1824 Liebig completed in Gay-Lussac's laboratory an investigation of the fulminates. Shortly before, Wöhler, working in the laboratory of Berzelius, had brought to a close a series of analyses of the cyanates. When comparing his results with those of Wöhler, Liebig was surprised to perceive that the composition of the two classes of substances was the same. At first he assumed that Wöhler's results were incorrect and carefully repeated the latter's work, without however detecting any error. Thus Wöhler and he were driven to admit that it was possible for two substances of the same composition to possess absolutely different properties, but this conclusion was not at once admitted by other chemists. Then followed, in 1825, the discovery by Faraday of benzene, erroneously supposed to be identical in composition with ethylene. Tartaric acid had been known since 1769, when Scheele, and after him Retzius, obtained it by the decomposition of calcium tartrate by sulphuric acid, and racemic acid had been discovered by Kestner, and investigated in 1826 by Gay-Lussac, who found that it required the same amount of alkali for neutralization as tartaric acid, and in 1830 by Berzelius, who satisfied himself of the complete identity of the two in composition and supposed, incorrectly, that they possessed the same molecular weight. In his account of the progress of chemical science during the year, he admits the existence of the phenomenon and proposes for it the name now in use.* He refers to the work of Liebig and Wöhler, and of Faraday, to the results of Clarke in phosphoric and metaphosphoric

*Berzelius, *Jahresbericht*, xi, 44 (1831).

acid, where the supposed identity of composition was erroneous, to his own investigations of the two stannic acids, and finally to racemic acid, which he considered a decisive example. He suggests, as an explanation, that compounds differing in this way, since the atoms are the same in number and kind, must possess different atomic arrangement, and adds that the discovery of Mitscherlich, that substances may contain different atoms and still crystallize in the same way, must now be supplemented by the fact that the same atomic complex may give rise to different crystallizations if the arrangement of the atoms is different. It is remarkable that the decisive example which caused Berzelius to admit the possibility of isomerism and to suggest a structural explanation should have been a case of that subtle kind where the explanation fails, and a spatial extension of the doctrine of atomic linking is necessary.

In 1848 Pasteur published his beautiful researches on the tartaric acids. The passage in which he announces his chief result is so germane to our present subject and of such great historical interest that I shall translate it.*

"I found that all the tartrates crystallize with hemihedral faces. In studying the double racemate of sodium and ammonium I noticed that these faces were differently placed in different crystals, sometimes at the right, sometimes at the left. I separated with care the right hand from the left-hand crystals and observed the solutions separately in the polariscope. With surprise and pleasure I saw that the solution from the right-hand crystals turned the plane to the right, that from the left-hand crystals to the left. Thus, starting from racemic acid I obtain in the usual way the sodium ammonium racemate, and the solution deposits, after some days, crystals which are alike in appearance and possess the same angles and yet, most certainly, the molecular arrangement of the two must be entirely different. The two species of crystals are isomorphous with each other and with the corresponding tartrates; each is the mirrored

*Pasteur, *Annales de Chim. et de Phys.*, third series, xxiv, 442; xxviii, 50. Also *Comptes Rendus*, xxiii, 535; xxix, 297; xxxi, 480.

image of the other. In fact, if, in both species, I suppose the hemihedral faces prolonged until they meet, I obtain two tetrahedra which are unsuperposable, and one of which is the reflection of the other. It was very important to investigate if, in the crystallization of the substance, there was deposited for each dextro-rotatory molecule, a lævo-rotatory molecule. Experiment leaves no doubt that this is the case.

"When the crystals are simply dissolved, without any selection, the solution is inactive, and the fact that equal quantities of the two salts are deposited is clear from the inactivity of the mother liquor." He prepared dextro- and lævo- neutral sodium tartrates from the corresponding crystals of the sodium ammonium salts, and finally obtained from each sodium ammonium salt its corresponding barium salt, and, decomposing these with sulphuric acid, prepared dextro- and lævo-tartaric acids.

In the first paper the identity of the dextro-acid with ordinary tartaric acid is expressed with reserve. Having obtained from Kestner, its discoverer, a large quantity of racemic acid, he returned to the subject in a paper published two years later, and established beyond doubt this conclusion, as well as the extraordinary resemblance between the dextro- and the lævo-acid. In crystalline form the two are identical, except for the enantiomorphism already referred to. On the right-hand crystals the left-hand hemihedral faces are sometimes absent, but more commonly present in imperfect state of development. Very rarely both sets of faces are completely developed in the same crystal, so that the asymmetry is only evinced in its action on polarized light. Their density and chemical composition are identical. Both kinds of crystals are electrically excited when heated or cooled. When the dextro-crystals are cooled the end containing the hemihedral faces becomes the positive pole; when heated, the negative. This same statement applies to the lævo-crystals. The rotatory power of both is the same, but is exerted in opposite directions, and this is true for light of every wave-length, so that the rotatory dispersion of dextro-tartaric acid, studied by Biot,

is found unchanged in the solutions of the lævo-acid. The rotatory power of both is decreased with falling temperature to an equal extent. This suggested to Pasteur a curious experiment. Since the solution of dextro-tartaric acid differs from that of the lævo-acid only in the sense of the rotation, and since the amount of the rotation is decreased by cooling, it occurred to him that it might, by cooling, be transformed into the lævo-acid, which would then unite with the unchanged dextro-acid to produce racemic acid. Of course the result was negative. The possibility that racemic acid was a mixture occurred to him. With the criteria at hand at that time the distinction between mixture and compound in such an extremely subtle case was a difficult one; nevertheless, he arrived at the correct conclusion. When the solutions of dextro- and lævo-sodium ammonium tartrates are separately treated with a soluble calcium salt no precipitate is produced at once, but there appear slowly crystals of the two tartrates, which are exactly similar in the two cases. But when the solutions are mixed and then the calcium salt added, there is immediately formed a precipitate of calcium racemate, in small plates, or an amorphous powder. From this he concluded that racemic acid was a compound. Pasteur found that, in general, the two optical isomers remained combined in the various salts, and when the salts were crystallized.

The behavior of the sodium ammonium salt was exceptional, and the only other racemate which he found to separate into the single tartrates when crystallized was the isomorphous sodium potassium salt. The determining influence of solubility and, through it, of temperature on the separation, escaped him. This is the classical case of optical isomerism, and it has been found since that many of Pasteur's statements are equally true in similar cases, and that dextro- and lævo-tartaric acids—the two antimeres* as

* This convenient term is due, I believe, to Lachmann: *Cf.* "Spirit of Organic Chemistry," p. 127. For convenience I shall also use the term enantiomorph, though it is not accurate.

we shall call them, and racemic acid, the inactive compound of the two—are typical examples of a whole class of substances. It is now in order to inquire to what extent Pasteur's results are of general application.

II. THE NATURE OF THE PHENOMENON.

At present the discussion is restricted to those compounds which rotate the plane of polarization in uncrystallized condition, that is, when they exist as liquids or vapors, or in solution. This phenomenon has thus far been observed only among the compounds of carbon, and only in those which contain a carbon atom whose four valences are satisfied by four different atoms or radicles, an asymmetric carbon atom. A further structural condition which must be fulfilled is that at least one of the valences of the asymmetric C must be linked directly to carbon, or the molecule must contain the group

$$\begin{array}{ccccc} & & a & & \\ & & | & & | \\ b & — & C & — & C_2— \\ & & | & & | \\ & & d & & \end{array}$$

where a, b and d may be anything, so long as they are not alike and C_2— is a monovalent radicle whose carbon atom is linked directly to the asymmetric carbon atom. The simplest compound, structurally, in which optical isomerism has been observed is chlor-brom-fluo-acetic acid.

$$\begin{array}{ccccc} & & Cl & & \\ & & | & & \\ Br & — & C & — & CO_2H \\ & & | & & \\ & & F & & \end{array}$$ *

When chlor-di-brom acetyl chloride is treated with a mixture of antimony trifluoride and bromine, the fluoranhydride of the acid, ClFBrC—COF, a very volatile liquid, is produced. By the action of alcohol, the F combined with carbonyl is readily replaced by ethoxyl, yielding the ethyl ester of the acid.

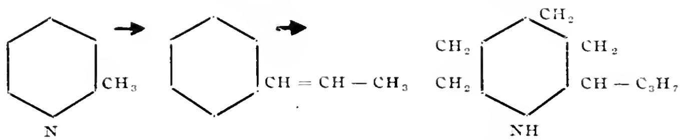
* Swarts, *Bull. de l'Acad. de Belg.*, 31, 28.

$$\begin{array}{c} Cl \\ | \\ Br—C—COOC_2H_5 \\ | \\ F \end{array}$$

and this is easily saponified by bases. The acid is a syrupy hygroscopic liquid: all of its salts are soluble in water. The strychnine and cinchonine salts can be separated into isomers of different rotatory power, and this shows the existence of optical isomerism in the acid. By heating the sodium or potassium salt with caustic potash or soda chlor-brom-fluo-methane is obtained. If this proves to exhibit optical isomerism, it will furnish the simplest conceivable case, and we shall have to drop the second structural condition. It has not yet been investigated in this respect.

If the asymmetric combination is situated in a ring it can still produce optical isomerism, provided that the aspects which the ring presents to the two valences of the atom in question are different.

Of course, if the ring had a plane of symmetry passing through the carbon atom, the latter would not be asymmetric. Thus Ladenburg's beautiful synthesis of conine from *α* picoline and paraldehyde, followed by reduction of the product,* has shown it to be *α* n-propyl piperidine.



Emil Fischer is undoubtedly right in his contention that the proofs Ladenburg advances for the racemic character of liquid synthetic conine are quite inconclusive,† but this does not affect the fact that optical isomerism exists in the case. The doctrine of the tetrahedral arrangement in space of the atoms or radicles attached to C‡ has become one

* Liebig's Annalen, ccxlvii, 81.

† *Berichte*, xxvii, 1525, 3224.

‡ Le Bell, *Bull. de la Soc. Chimique*, second series, xxii, 337. Van't Hoff, *Ib*, second series, xxiii, 295.

of the commonplaces of chemical theory, and it is unnecessary here to do more than refer to the fact that this natural extension of the structural idea has furnished a very satisfactory explanation of the matter.* When, therefore, the structural peculiarity just noticed is present in the molecule, the existence of optical isomers is to be expected, and the two compounds are found to exhibit an astounding resemblance which extends to many of the minutest details of chemical and physical behavior. The most conspicuous difference is the rotatory power, which is equal in amount but opposite in sense.† Differences exist in their relations to

* The stereo-chemistry of nitrogen cannot be discussed in the present paper. But it is desirable to point out that very recent results indicate that the presence of pentavalent nitrogen united to five different radicles can produce molecular asymmetry quite analogous to that conditioned by the carbon atom. Eight years ago Le Bel announced the optical activity of methyl-ethyl propyl-isobutyl ammonium chloride

$$N(CH_3)(C_2H_5).(C_3H_7)(C_4H_9)Cl.$$

His results have recently been sharply questioned by Marckwald and von Droste-Huelshoff (*Berichte*, xxxii, 560 (1899)), but Le Bel has replied, giving details and maintaining the correctness of his observations (*Comptes Rendus*, cxxix, 548). Still more recently Pope and Peachey have announced the preparation of dextro- and lævo-benzyl-phenyl-allyl-methyl ammonium iodide and bromide, *e. g.*,

$$N(CH_2C_6H_5)(C_6H_5)(C_3H_5)(CH_3)I.$$

The results indicate that the pure antimeres have equal and opposite rotatory power, so that so far the analogy of the phenomena to those of the asymmetric carbon atom is complete (*Jour. Chem. Soc.*, xv, 192).

† The subject of the variation in rotatory power with the conditions under which the substance is placed lies outside the scope of the present paper. But it is necessary to remark that in order for the antimeres to exhibit equal and opposed rotatory power they must be rigorously under the same conditions, and, so far as we know at present, interpolations and especially extrapolations from observations made at other temperatures and concentrations are absolutely inadmissible, for with the variation of these conditions the rotatory power changes its amount and even its sign. The character of the solvent and the presence of various inactive substances in the same liquid also affect it profoundly. The effect of the solvent ceases to be surprising when we consider the very different conditions in which the same dissolved substance may exist in different liquids. It is not astonishing that the ions should rotate differently from the undissociated molecule, and this in turn from the double molecule. Here are some of the facts, mostly from the extremely interesting paper of Walden (*Berichte*, xxxii, 2849 (1899)). The rotation of aqueous solutions

other asymmetric substances. Thus, if the substances in question are acids they will combine with the same asymmetric base with different speeds, and the two salts will possess different solubilities.

The enantiomorphous crystallization of the antimeres has been erected into an article of faith, partly because of the simplicity and beauty of the conception and partly because it harmonizes well with modern views of crystalline structure.* But the facts are completely opposed to such a generalization. It has just been noticed that even in Pasteur's typical case the enantiomorphism is only of occasional occurrence. And, over the whole field, the number of optical isomerides which do not crystallize enantiomorphously, and must be ranked as exceptions, is greater than that of those which obey the rule.† It is, of course, possible to assume that all of the innumerable exceptions will be found to be enantiomorphous, but this is a most inadmissible procedure. Since the optical activity of the two antimeres is equal and opposite, it is clear that a solution containing both in equal quantity will produce no rotation. The substance containing both in equal quantities, merely mixed, is called the inactive mixture. It is an ordinary mechanical mixture, and derives its importance from the

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of ordinary d-tartaric acid becomes less with increasing concentration, and very strong solutions are lævo-rotatory. So, also, is the anhydrous substance. Dilute solutions in water of ordinary natural malic acid are lævo-rotatory, but with increasing percentage the activity decreases, the solution becomes inactive and finally dextro-rotatory. The same malic acid is lævo-rotatory in water, acetone, acetaldehyde, isobutyl alcohol, acetophenone and most other solvents, but dextro-rotatory in benzyl alcohol and in mixtures of the latter with benzene and carbon disulphide. Its strong solution in anhydrous formic acid is feebly lævo-rotatory at ordinary temperatures, and feebly dextro-rotatory at 0°. Fused malic acid is lævo-rotatory at moderately elevated temperatures, but at about 40° the optical activity changes sign, and with further cooling the substance becomes increasingly dextro-rotatory. It will be seen from these facts that the decision which acid to name dextro- and which lævo- is not so exceedingly easy as it might appear at first glance. Fortunately the fundamental contention that *under the same circumstances* the optical activity of the two antimeres is equal and opposite remains entirely undisturbed.

* Even van't Hoff falls into this error. "Vorlesungen über Theoret. Chemie," ii, 98 (1899).

† Walden, *Berichte*, xxix, 1693.

frequency with which it is obtained in chemical operations. The enantiomorphs being perfectly symmetrical, their chances of being produced in a symmetrical synthesis are equal. Hence the products of a synthesis in which a carbon atom becomes asymmetric are inactive, and the isomerism is only evident when the antimeres are separated.

The existence of a racemic compound of the two antimeres appears to be a general phenomenon. This is perfectly distinct from the mixture, being a homogeneous chemical substance, whose density, crystalline form, solubility, etc., are different from those of the antimeres. It is universally held that it possesses double the molecular weight, racemic acid, for example, being written $(C_4H_6O_6)_2$, and corresponding formulas set up for the racemates, but it is impossible to find any basis for this belief. It is, in fact, impossible to determine the molecular weight of a racemic compound, for our methods of determining molecular weight are valid only for solutions, gases and vapors, and when applied to racemic compounds, the result obtained always corresponds to the simple molecular weight of one antimere, so that we must assume that they dissociate into the enantiomorphs when vaporized or dissolved.

The same conclusion is arrived at from the study of the physical properties of their solutions and from the fact that solutions of the antimeres exhibit no evolution or absorption of heat when mixed.*

The question regarding the existence of racemic compounds in the liquid state is entirely an open one, and I know of no facts which forbid our making the assumption, tentatively at least, that they exist only in the solid state.

Küster † has attempted to show that the solubility relations can be best explained by the assumption that the racemic compound exists in solution. But the solubility of a racemic compound is an extremely complex phenomenon and is affected by a number of factors, among which are the number of racemic molecules in the solution,

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*Jahn, "Wiedemann's Annalen," xliii, 306 (1891).

† *Berichte*, xxxi, 1847 (1898).

the extent to which the racemic molecules are electrolytically dissociated and the extent to which the antimeres are ionized. Further, if one works with the pure racemic compound, and the antimeres are not present as solid phases, the possibility of supersaturation with respect to them must be kept in mind. Such considerations, therefore, as Roozeboom has remarked, are valid only for very slightly soluble substances.

The recent death of the young Italian chemist, Andreocci, left unfinished an interesting investigation of the triboluminescence of racemoid and antimeric forms.*

Triboluminescence is simply the flash of light which is emitted at the time the crystalline structure is destroyed, either by grinding or splitting. The work must be done in complete darkness. The conclusions cannot be regarded as of universal validity, since they were obtained purely by experiments on the santonine derivatives and elsewhere different relations may prevail. The general results are these. Optically active substances are not necessarily triboluminescent; some exhibit the phenomenon intensely, others feebly, others still, not at all. All the well-characterized antimeres examined were triboluminescent, and the isomers are just as similar here as they are in all other respects, giving out exactly the same kind of light when crushed. The light is yellowish-green or emerald green. Racemic compounds never exhibit the phenomenon. Partially racemic compounds may be triboluminescent.†

Regarding the conditions under which the antimeres unite to produce the racemic form, some generalizations are at hand. It is clear thermodynamically that if the isomers unite with evolution of heat, their compound will be decomposed by heat and that they will reunite on cooling, while if they unite with absorption of heat the reverse will be true. Many cases of both are known. Further, a racemic compound is simply a double salt, though a double salt of a very special kind, and the views that have proved useful in

* *Gaz. Chimica Italiana*, xxix, 519.

† The phenomena of partial racemism will be discussed later.

dealing with double salts in general are applicable here. For some time it has been evident that in a system in which a double salt exists only as solid phase the direction of the charge at the inversion point can be foretold if we know the amounts of water of crystallization in the double salt and in the component single salts. It is found that if the double salt is poorer in water than the single salts taken together, it is formed from the single salts on heating; if it contains more water, the reverse is true.* This is just as true of racemic compounds as it is of other double salts.† Thus racemic ammonium malate separates at 73° into the dextro and lævo isomers. Below this temperature the racemic form is stable; above it, the separate salts. Now the antimeres are anhydrous and the racemic form, if we use the conventional double molecule, crystallizes with two molecules of water. Hence the reaction is

$$(C_4H_5O_5NH_4)_2 2H_2O = d.C_4H_5O_5NH_4 + l\text{-}C_4H_5O_5NH_4 + 2H_2O,$$

the change taking place with elimination of two molecules of water. On the other hand, when a mixture of the dextro- and lævo-sodium ammonium tartrates is heated to 27° the racemate is produced, thus

$$\begin{gathered} d\text{-}C_4H_4O_6NaNH_4.4H_2O + l\text{-}C_4H_4O_6NaNH_4.4H_2O \\ = (C_4H_4O_6NaNH_4)_2 2H_2 + 6H_2O, \end{gathered}$$

six molecules of water being set free as a result. It seems that the production of the racemic form is accompanied in general by a decrease in volume. This statement is called Liebisch's rule, and is expressed in the following form:

"Die Verbindung der optisch isomeren Körper zu einer krystallisierten racemischen Verbindung findet unter Contraction statt." Walden concludes, from the examination of a large amount of material, that it is applicable to all cases thus far studied.‡

There is at present no relation connecting the melting point of a compound with those of its constituents, and this

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* Bancroft, "The Phase Rule," p. 180 (1897).

† Van't Hoff, *Berichte*, xxxii, 857 (1899).

‡ *Berichte*, xxix, 1693 (1896).

is true also of the compounds composed of optical isomers. The racemic derivative is simply a new form of matter, with its own melting point, which may be higher or lower than that of its constituents.

It is to be remembered that the antimeres have the same melting point. The cases mentioned by Walden in which the racemic form has the same melting point as its two constituents are certainly very surprising, but they can hardly be more than accidental. The most natural supposition is that these substances were in reality mix-crystals, or solid solutions, in which case they would possibly, though not necessarily, behave in this way; but this assumption is contradicted by the fact that they possessed a distinctly different crystalline form from that of the antimeres. Melting point determinations of these substances are much complicated by the possibility of change of crystalline form on heating—these compounds seem to exhibit polymorphism with unusual frequency—and, on the whole, as we shall see, the determination of the melting point has little or no diagnostic value.

The phenomena when the racemic form is produced from the antimeres, or separates into them, are nearly those of the formation and separation of double salts. The chief difference is that the precisely equal solubility of the two isomers at all temperatures very greatly simplifies matters. Systems in which a double salt is possible will, in general, contain three components, the two single salts and the solvent, usually water.* Five phases will completely determine the system; three solid substances, solution and vapor, for example. For our purpose the complications introduced by the presence of different amounts of water of crystallization can be neglected, and the only solid phases we need consider are the two component salts and the double salt

* The Gibbs Phase Rule and the associated deductions furnish the only point of view from which the passage from the antimeres to the racemic form and reversely can be properly regarded. It is, of course, impossible to discuss this extensive subject in the present paper. The only complete account of the matter, fortunately an excellent one, is by Bancroft—"The Phase Rule" (Ithaca, 1897).

formed from them. The phase rule informs us that the presence of these three solids in equilibrium with solution and vapor will occur at an inversion point. An inversion is a state of things analogous to the equilibrium of ice, liquid water and water vapor. The phases can only coëxist in equilibrium at one particular temperature, and the addition or subtraction of heat will produce no alteration in temperature until it has brought about the disappearance of one or more of the phases. When, for example, the double salt schönite is cooled slowly in contact with its saturated solution, the thermometer remains stationary at — 3° until the reaction:*

$$K_2Mg(SO_4)_2 6H_2O + H_2O = K_2SO_4 + MgSO_4 7H_2O$$

is complete, *i. e.*, until the solid phase schönite has disappeared. And when the mixture of potassium and magnesium sulphates is again allowed to heat, the thermometer again remains stationary until the reverse change.

$$K_2SO_4 + MgSO_4 7H_2O = K_2Mg(SO_4)_2 6H_2O + H_2O$$

is over, and the two single salts as solid phases have disappeared. It will be perceived that the thermometer furnishes one method of locating the inversion point. Another is given by the dilatometer. This consists essentially of a bulb ending in a capillary tube. The bulb contains an intimate mixture of the two component salts, or else the powdered double salt, and the interstices of the powder and a portion of the capillary tube are filled with some liquid which is assumed to have no effect on the process, *e. g.*, petroleum. If the apparatus is very slowly heated there will be the usual expansion, shown by a slow rise of the oil column, but when the point is reached at which the double salt splits up, or is formed, as the case may be, a change of volume due to the chemical reaction in the bulb, a change of a higher order of magnitude than the thermal volume changes, will appear. This may be either positive or negative, and its appearance locates the temperature in question.

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* Van't Hoff, *Vorlesungen über Theoret. Chem.*, i, 76 (1898).
Bancroft, "The Phase Rule," p. 165 (1897).

In the practical use of this apparatus it must be remembered that the impossibility of heating the system above the inversion point, until the change has occurred, refers only to the impossibility of the existence of the same system in stable equilibrium on both sides of the inversion point. It is true without modification of one physical change, the melting point of a solid, for a solid cannot be heated above its melting point, but in chemical changes the slowness of the change and the possibility of unstable equilibrium complicate matters, and the statement applies only to the ideal limiting case where the heat supply is so slow that all of it can be consumed by the chemical change. Nevertheless, if the heating be sufficiently slow, the dilatometer will show a very noticeable maximum of alteration of volume in the neighborhood of the inversion point. Then the temperature in question can be accurately fixed in a somewhat different way. Let us assume that the double salt is formed from its constituent single salts in presence of the saturated solution with absorption of heat and separation of water of crystallization. Then it will be produced from them on heating, and below the inversion point the two single salts will be in stable equilibrium with the solution as solid phases, above it the double salt. If the proper precaution to avoid supersaturation with respect to the double salt is taken, its formation will begin at the inversion point. But since the change occurs slowly it will in general be possible to heat the system containing the three solid phases above the inversion point. Here the system cannot be in equilibrium, and the change of the single salts into the double salt will occur. In the same way it will be possible to cool the system below the inversion point, but here the direction of the change will be reversed, and the double salt will decompose. For the sake of definiteness let us make the purely arbitrary assumption that when the double salt is produced expansion takes place. Then it is evident that at any temperature above the inversion point the level of the oil will rise, at any temperature below it will sink. These changes are easily distinguished from thermal volume changes, since they continue when the

apparatus is maintained at a fixed temperature, which, of course, is not the case with ordinary expansion and contraction. Practically, therefore, the inversion point is the point at which the volume alteration changes its sign.

Much of our knowledge of this subject is due to Van't Hoff, and we owe to him also the proof that the formation and separation of racemic compounds are in all respects to be classed with ordinary double salt phenomena.* The reaction investigated was the classical one, the transformation of dextro- and lævo-sodium ammonium tartrates into the racemate :

$$2C_4H_4O_6NaNH_4.4H_2O = (C_4H_4O_6NaNH_4)_22H_2O + 6H_2O.$$

Since the racemate is formed with separation of water, we should expect it to be produced on heating. Little had been done since the time of Pasteur to clear up the nature of the change. Bichat had speculated obscurely about the influence of "germs" from the atmosphere—the "germs" in question being minute crystals or dust promoting crystallization—and had shown that in sealed tubes the phenomena were irregular. Wyrouboff,† in a remarkable paper, had pointed out clearly that temperature was the determining factor, and was so through its different effect upon the solubility of the racemate and the single tartrates. He remarks that if one evaporates the solution of the mixed tartrates in the usual way, that which crystallizes will be the substance least soluble at the temperature. Above 28° the racemate is always obtained; below, the single tartrates.

The only function of the "germs" is to exclude supersaturation, which may play a disturbing rôle when one works in sealed tubes. In the work of Van't Hoff and Van Deventer, the change in question was, for the first time, studied from the same standpoint as the behavior of other double salt reactions. The results which interest us are these :

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* Van't Hoff and Van Deventer, *Zeitschrift für Physikal. Chem.*, i, 173 (1887).

† *Comptes Rendus*, cii, 627 (1886).

(1) Powdered sodium ammonium racemate, mixed with water to a thin paste under 27°, solidifies completely to a dry mass of the single tartrates. Over 27°, this does not occur.

(2) The finely powdered mixture of the two tartrates remains completely unaltered under 27°. Above this temperature the formation of the racemate occurs and the free water produces liquefaction.

(3) The inversion temperature can be more accurately estimated by the dilatometer. Between 26·7° and 27·7° there is a great expansion, partial liquefaction occurs and the monoclinic crystals of the racemate can be plainly seen.*

[*To be concluded.*]

CORRESPONDENCE.

WHAT IS PARIANITE?

A CORRECTION BY DR. ENDEMANN.

Editor of the Journal of the Franklin Institute.

DEAR SIR:—I desire to correct a misstatement which appears in Dr. Keller's contribution to the discussion of Professor Peckham's paper in the March impression of the *Journal*. This error is due either to my misunderstanding of a question or to a misapprehension on the part of Dr. Keller.

I understood him to ask whether I had made any efforts to isolate compounds of definite composition from the petrolenes, and answered negatively.

As the report of the meeting reads, it would seem that I had made no efforts to isolate compounds of definite composition from asphalt generally.

As it is, I have neglected the petrolenes altogether, these being the subordinate portion of asphalt. Asphalt differs from petroleum by reason of the predominating presence of solids. In examining the solids of asphalts, I have done all my work, and have made not only efforts to isolate, but I think I have isolated, compounds as far as it is possible at the present time, for I have never yet been able to produce a crystalline compound.

Very truly yours,

H. ENDEMANN.

NEW YORK, March 14, 1900.

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* There is here no conflict with Liebisch's rule. It is the water split off which produces the expansion.

BOOK NOTICES.

Leçons sur l'Electricité, professées à l'Institut Montefiore. Par Eric Gérard, Directeur de l'Institut électrotechnique Montefiore. 6e édition, 2 volumes grand in-8. 1899-1900. (Paris: Librairie Gauthier-Villars. Prix de chaque volume: 12 francs.)

The circumstance that a work has reached its sixth edition within a few years is, of itself, fairly good evidence that it has a *raison d'être*. Aside from this generalization, the work is fairly representative of the present theory and practice of electricity. The work is printed in two volumes, the first devoted to the theory of electricity and the modes of its production; and the second to the industrial applications of electricity based on the mechanical, luminous, calorific and chemical effects of the electric current.

The second volume is the subject of this notice. The author appears to have omitted nothing in this edition that is necessary to bring his work up to date. W.

Encyclopédie scientifique des Aide-Mémoire. Small 8vo. Paris: Gauthier-Villars. 1899. Price, per volume, 2.50 francs in paper; 3 francs in cloth.

Since the last notice of this valuable series of hand-books for engineers, the following volumes have been issued from the press. The entire series forms an exceedingly compact body of reference literature on almost every scientific and technical topic now engaging attention. The authors are generally men of note in their specialties, and their works appear to be well brought up to date. W.

Seyrig (*T.*), Ingénieur-Constructeur. Statique graphique des systèmes triangulés. I. *Exposés théoriques*. II. *Exemples d'applications.*

Vigneron (*E.*), ancien Professeur à l'École supérieure d'Électricité, Ingénieur au Service technique de la Cie générale des Omnibus, et *Letheule* (*P.*), Ingénieur à la Cie Thomson-Houston. Mesures electriques. *Essais de laboratoire.*

Gouré de Villemontée, ancien Élève de l'École Normale supérieure, etc. Résistance électrique et fluidité.

Minet (*Adolphe*), Ingénieur, Directeur du journal *L'Electrochimie*. Analyses électrolytiques.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. La liquéfaction des gaz et ses applications.

Niewenglowski (*G. H.*), Préparateur à la Faculté des Sciences de Paris, Directeur du journal *La Photographie*. Applications de la Photographie aux Arts industriels.

Dariès (*Georges*), Conducteur au Service des Eaux de Paris. Calcul des canaux et aqueducs.

Pozzi-Escot (*M. E.*), Chimiste, Rédacteur au "Praticien industriel," etc. Analyse chimique qualitative.

Laurent (*P.*), Ingénieur au Polygone du Hoc. Résistance des bouches à feu.

Leloutre (*G.*), Ingénieur civil. L'échappement dans les machines.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 21, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1900.

Vice-President THEO. D. RAND took the chair at 8 o'clock P.M.

Present, 42 members and visitors.

Additions to membership since last report, 29.

A communication was read from Mr. Howard B. French, accepting election to the Board of Managers.

Mr. A. L. Hahl, of Chicago, exhibited and described his pneumatic time-controlling and distributing system, illustrating the subject with the aid of one of his synchronizing master-clocks controlling a number of clock-dials connected therewith.

The Secretary, in his report, called attention to the arrangements which had been made in the interest of members desiring to visit the World's Fair shortly to be opened in Paris; also, to the total solar eclipse, to take place on May 28, 1900, and which will afford residents of the eastern portion of the United States a convenient opportunity for observation, the path of totality being in about the latitude of Norfolk, Va. It was also stated that the Physical and Astronomical and the Photographic Sections of the Institute would probably take steps, at the proper time, to arrange for an excursion of their members and of the members of the Institute generally to witness the occurrence, and probably to unite with other scientific bodies in the work of observation.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, March 7, 1900.*]

MR. WM. PENN EVANS in the chair.

The following reports were adopted:

Water-Heater for Range Boilers.—Adam Heller, Baltimore, Md.

ABSTRACT.—This device is designed for heating the water contained in vertical circulating boilers attached to water-backs of kitchen ranges, when no fire is in the range. It consists of a flat cylindrical gas burner of the Bunsen type, having on its upper surface numerous gas jets. One side of the burner chamber has a radial slot extending to the center to allow the burner to be

placed under the boiler, the slot encircling the central pipe usually attached to the lower head of such boilers, and the burner is fastened to the pipe by a simple form of clamp. The burner is, of course, connected suitably with the gas supply.

The report finds that while other inventors have attached closed vessels to either the circulating boiler or to its connecting pipes, these appear to have invariably required alterations of either pipes or boiler, and that Mr. Heller appears to be the first to accomplish the desired result with a device requiring no such alterations. The device is pronounced to be new, convenient and useful, and the applicant is awarded the Certificate of Merit. [*Sub-Committee*, Spencer Fullerton, Chairman; Frank P. Brown.]

Respiration Calorimeter.—A. O. Atwater and E. B. Rosa, Middletown, Conn.

ABSTRACT.—The object of this apparatus is to measure the energy of food and its metabolism in the human body—in other words, to permit of the exact study of the income and outgo of food in the animal organism and the energy generated thereby.

Reserved for publication in full.

The report recommends the award of the Elliott Cresson Medal to Professors Atwater and Rosa, and makes honorable mention of Dr. F. G. Benedict, Mr. A. W. Smith, Mr. O. S. Blakeslee, Mr. A. P. Bryant and Dr. O. T. Tower. [*Sub-Committee*, Prof. H. W. Wiley, Chairman; Prof. Geo. F. Stradling and Dr. Robt. H. Thurston.]

Pneumatic System for Preventing the Bursting of Water-Pipes by Freezing.—N. Monroe Hopkins, Washington, D. C.

ABSTRACT.—This invention involves the application to a house water-supply line of an automatically-operating air injector, situated usually where the service pipe enters the building, and which admits air to the pipes every time a faucet is opened; and in connection therewith, a series of air-domes, introduced at regular intervals along the line, wherever the pipes are exposed to liability of dangerous expansion from freezing during cold weather.

After giving the results of a series of comparative experiments made with lengths of water pipes protected with the Hopkins device, and unprotected, by exposing them to freezing by exposure in cold weather, and in an artificial freezing mixture, which resulted uniformly in the bursting of the unprotected pipes, while that provided with the Hopkins device escaped injury, the report concludes that the Hopkins device has great merit, and is of great importance. The Scott award is recommended to the inventor. [*Sub-Committee*, J. J. De Kinder, Chairman; John W. Edmundson, Frank P. Brown.]

Stereoscopic Camera.—John G. Baker, Philadelphia.

ABSTRACT.—This apparatus consists of a camera of ordinary construction and long extension, to which the inventor has added various attachments and devices to adapt it specially for the work of making stereoscopic photographs of insects and similar objects which are too large to be photographed successfully, by attaching a camera to the ordinary microscope, yet not large enough to permit of the employment of an ordinary stereoscopic camera.

The report concludes that the apparatus shows considerable ingenuity of adaptation, and that the photographs of insects obtained with the Baker camera with little trouble prove it to be admirably adapted for the special work for which it is intended. [*Sub-Committee*, F. E. Ives, Chairman; W. N. Jennings, Louis E. Levy.]

Portable Photometer.—Charles Deshler and Edwin J. McAllister, Newark, N. J.

ABSTRACT.—This instrument consists of a Bunsen or grease-spot screen, mounted above a scale which is divided to read candle-powers. At one end of the instrument is placed a standard 16 candle-power incandescent lamp, with a rheostat for controlling the voltage at the lamp terminals, and suitable connections for a voltmeter and an ammeter. At the other end is placed an oil lamp of about 32 candle-power, which is used as the working standard.

The photometer is used as follows: Having placed the standard incandescent lamp in its socket and brought it to its marked voltage, the screen is placed at 16 on the scale and the oil lamp is adjusted until the grease spots disappear or balance. The oil lamp then becomes the working or secondary standard.

The lamps to be measured are now substituted for the standard incandescent lamp, and the candle-power read directly in the usual way. The use of the oil lamp in place of an incandescent obviates the use of two voltmeters.

The lamp to be measured is supported on a spindle which is provided with mercury cups to make electrical connections to the lamp. In one form of the instrument the spindle is rotated either with a spring motor or an electric motor.

The apparatus is made in three sections, so devised as to pack together in a case, making a very portable arrangement, by which commercial or mean horizontal candle-powers may be obtained by direct reading.

The novel features of the instrument have reference to the arrangement of its parts and not to the use of the secondary standard, which has been known and used previously.

The report finds the instrument to be well adapted for its intended purpose. The inventors are awarded the Edward Longstreth Medal of Merit. [*Sub-Committee*, Arthur J. Rowland, Chairman; Geo. F. Stradling, D. Anson Partridge, Francis Head.]

The following reports passed first reading:

Electric Meter.—Wm. D. Marks, Philadelphia.
Press for Baling Cotton, etc.—Geo. A. Lowry, Chicago, Ill.
Round-Lap Baling System for Cotton.—American Cotton Co., New York.
Improvements in Steam Injectors.—Strickland L. Kneass, Philadelphia.
Rail-Joint.—Harry Vellenoweth, Philadelphia.

These were held under advisement for one month.

The following reports were made advisory and adopted:

Electrical Switch.—Paul A. Medary, Cynwyd, Penna.
Hydraulic Air-Compressor.—Albert A. E. Sterzing, New York.
Improvement in Valves.—Joseph F. Batchelor, Philadelphia.

W.

SECTIONS.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The first stated meeting of the Section was held on Tuesday, March 6th. Dr. Henry Leffmann in the chair.

Present, 55 members and visitors.

The questions of adopting a code of regulations and nominations for officers were referred to the Executive Committee, with instructions to report at the next stated meeting.

Dr. Leffmann addressed the meeting on the "Theories of Photographic Development." He pointed out that most of the modern developers in photography are benzene derivatives, and partake of the character of that substance in being rather difficult of complete oxidation, and hence exercised restricted reducing action. The localization of the deposited silver upon the impressed portions of the latent image may be due to the difference in electric potential owing to the disturbance in the homogeneity of the film. This condition naturally establishes a polarity which would cause a selective deposition of the silver.

Mr. F. E. Ives followed with a description of the practical remedies for the difficulties encountered from under- and over-exposure.

Mr. John G. Baker exhibited and described an ingenious apparatus for determining the time of shutter exposure.

A general discussion followed on methods of preparing lantern slides.

F. W. SAWYER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, March 8th. Mr. Wilfred Lewis in the chair.

Present, 32 members and visitors.

The following officers were elected for the current year: President, John F. Rowland, Jr.; Vice-Presidents, Arthur Falkenau, Spencer Fullerton; Secretary, Daniel Epplesheimer; Conservator, Dr. Wahl.

The subject for discussion was "Portable Machine Tools," and was opened by Horace G. Hoadley, of Waterbury, Conn. Mr. Hoadley exhibited and described several improved forms of portable tools made by the Waterbury Tool Company, notably an improved form of ratchet drill for drilling in close places where no other ratchet can be used for lack of room for the movement of the handle. He also showed and described a portable tool for screwing up and unscrewing nuts in similar situations.

Mr. James Christie spoke of the great utility of portable pneumatic tools in modern shop practice and of the great development of the manufacture of tools of this class. He gave some account of his experience with electrically-driven tools for similar uses, and of the difficulties he had encountered in the attempt to make serviceable tools of that class.

Mr. W. R. Webster gave a brief account of his experience in attempting to devise a practical pneumatic riveter.

Mr. J. Logan Fitts and Mr. Spencer Fullerton spoke in general terms of the relative importance of the several classes of portable tools in erection and repair work. W.

Mining and Metallurgical Section.—*Stated Meeting*, held Wednesday, March 14th. Mr. Joseph Richards in the chair.

Present, 26 members and visitors.

The evening was devoted to the discussion of the paper read last spring by Mr. Paul Kreuzpointner, of Altoona, Pa., entitled "Riddles Wrought in Iron and Steel," in which the author set forth a number of contradictory and apparently inexplicable anomalies encountered in the manipulation of these metals.

The discussion was opened by Mr. Wm. R. Webster, who urged, in answer to some of the difficulties raised by the author in connection with the heat treatment of steel, that they are readily comprehensible and manageable when all the data are known.

Mr. A. E. Outerbridge, Jr., followed with some remarks upon the heat treatment of cast iron, in the course of which he made the announcement that, contrary to the usually accepted opinion, this alloy is materially weakened by annealing, and can be hardened, like steel, by rapid cooling. The weakening the speaker attributes to the change of the carbon of the alloy from the combined to the graphitic state. His experiments were made on soft gray iron.

Messrs. James Christie, Asa W. Whitney, Francis Schumann and the Chairman joined in the discussion, and a number of contributions were received by letter. The paper and discussion will be published in full in the *Journal.*

G. H. Clamer,
Secretary.

Chemical Section, Electrical Section, Physical and Astronomical Section.—A joint meeting of the three sections was held on Tuesday evening, March 20th, at 8 o'clock.

Present, 64 members and visitors.

Dr. W. J. Williams in the chair.

The meeting was devoted to the presentation of a paper entitled "Experimental Studies of the Acetylene Flame," by Prof. Edward L. Nichols, Cornell University.

Professor Nichols considered the acetylene flame with reference to its use in the physical laboratory, rather than from the industrial side. He referred to the influence of age and of the mode of production of the gas on the brightness and color of the flame; to the properties of the flames of mixtures of acetylene and hydrogen; to the structure of the flame with reference to its use in photometric work; to its color, radiant efficiency, etc., etc.

The paper was concluded by a consideration of the merits and demerits of acetylene as a standard in spectro-photometry and in ordinary photometric operations, and the precautions which it will be necessary to take in the establishment of a reproducible primary standard. (This paper will shortly be published in full.) W.

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Mining and Metallurgical Section.

Stated Meeting, held March 14, 1900.

RIDDLES WROUGHT IN IRON AND STEEL.

BY PAUL KREUZPOINTNER,
Altoona, Pennsylvania.

In view of our apparently extensive knowledge of the nature of iron and steel, it may seem strange to still speak about riddles wrought in these metals.

Nevertheless, in everyday practice we are constantly confronted by riddles of one kind or another, when dealing with iron and steel, particularly the latter.

One's ingenuity is sometimes taxed severely to find an explanation for the cause of such riddles.

We pour some fluid iron or steel into a mould, and what have we?

A metal liable to puzzle us with various kinds of often contradictory phenomena which may be of no consequence, or perhaps be annoying and sometimes hurtful.

We congratulate ourselves on having taken all precautions to insure a good casting, when lo! we hear a crack and

find the subject of our pride a useless mass of metal. We say it was caused by shrinkage.

Can any one describe the laws according to which the various elements of which the metal is composed aggregate to themselves the proper percentage of the most congenial elements at the proper degree of heat in the most suitable time and in such a position as to be torn apart *en masse* at a given point during the cooling of the mass, and what causes the casting to crack on account of shrinkage?

We know well enough how internal strains end, provided they end injuriously, if not disastrously, but who can solve the riddle of how they begin, how they progress, and how they stop just within, or far below, the point of rupture, as the case may be?

The riddle becomes no less puzzling if we roll that steel, if it was steel, into plates, use those plates for several years and then all at once some of them begin to crack lengthwise and crosswise and are so brittle that a blow with a hand hammer breaks off strips of the material. Yet that steel met all chemical requirements and physical specifications before the plates were put in service and after they had disastrously failed.

When some twelve years ago the author called the attention of a foreign steel-maker to the fact that soft steel was being used very successfully in this country for boilers, he said that would never do.

He had known of steel plates cracking while leaning against a wall. Now, is this not curious? Why should steel plates crack after they had passed rigid specifications? And why should there be greater success in the use of steel in one country than in another?

After you have solved this riddle I have another for you.

Why is it that one man softens a piece of steel by annealing, while another man anneals an identical piece of steel and finds it has become harder when his object was to get it softer?

Here are a few figures.

Wire with 49,200 pounds per square inch when unannealed was found to have a strength of 54,400 and 55,800 per

square inch after annealing for several minutes in a temperature of from 1,400° to 1,500° F.

In a series of twenty pieces of soft steel the author found not one of them softer after annealing. Two of the pieces were of the same strength and elongation as before annealing and all the others were harder and lower in elongation.

Why is it that we can raise the strength of soft staybolt iron of, say 47,000 pounds per square inch, to 60,000 pounds per square inch either by heat treatment, or by repeated application of stress?

Perhaps all of you have come across the man who knows it all.

If you meet him again please ask him to give the reasons why steel coming from the rolls or hammer is weaker, and less ductile, than the same steel is after left lying a day or two, or, better still, a week. Mr. A. A. Stevenson confirmed this here recently.

There is no doubt that many tons of suitable material have been either thrown out by the mill people themselves or were rejected by the inspector because it failed to meet specifications, causing needless vexation and friction simply because neither the one nor the other of the parties knew that steel is in a disturbed physical state after rolling or hammering, no matter how good the material, and should be left to rest, the longer the better.

Now, what takes place in the steel during the period of rest?

Another riddle is that we can raise the elastic limit and ultimate strength by a successive application of stresses very much above the original strength.

What law, if it is a law, governs this phenomenon?

Personally, the author is convinced that many errors of design or inherent weakness of the steel have been modified in their probable consequences, and breakdowns averted, by this pecular property of steel to gain in strength, if allowed to rest after having been subject to stresses within certain limits. It was the knowledge of this fact which enabled the author to fight for steel and defend steel for

structural purposes at a time when that metal was not yet a favorite with the engineer by any means. We are all familiar with Mr. Outerbridge's discovery of cast iron getting stronger by tumbling in the tumbling barrel, but for all we know it is still an unsolved riddle what the conditions really are producing such effects.

There is reason to believe that a similar phenomenon takes place in steel and, by analogy, in other cast metals. In looking over a table of the different degrees of temperature at which a certain number of plates were rolled, from the first pass to the last, I found one plate where the temperature remained 1,900° F. during three successive passes.

In another plate, an inch thick, the temperature likewise remained 1,900° F. during three successive passes.

In still another one the temperature oscillated between 2,190° and 2,200° F. during five successive passes.

Is this not a riddle?

When we look over the large field of results obtained by subjecting steel to strains of one kind or another we observe an almost endless variety of phenomena, which, on account of their frequent occurrence, may be familiar enough to us, but as to the reasons why, we are profoundly ignorant, showing us that our knowledge of steel is still rather fragmentary, notwithstanding the great strides we have made in the knowledge of the properties of that valuable metal.

If we heat a steel bar at one end, having it divided previously into inch lengths, and then break off the pieces, one after another, we will find the structure of the fifth or sixth piece very much different at both the fractures, though they are only 1 inch apart. Either one of the fractures is coarse-grained and the other very fine, or the one is granular and the other amorphous.

What does such a puzzling phenomenon teach us? Sometimes we are taught something which in after life we find not to be correct. Thus fifty years ago I was taught in school that elephants could not get up if they ever fell down. I was very much surprised when I saw an elephant for the first time and found he could lie down and get up like a horse.

We have likewise been told that elongation is proportionate to strength. That the one increases as the other decreases, and *vice versa*.

Everyday experience does not bear out this assertion. Looking over a list of 150 tests of steel of the axle grade, ranging from 74,000 to 103,000 pounds per square inch, an elongation is found of 27 per cent. at 76,000, 88,000 and 96,000 pounds strength. 20 per cent. is associated with every result from 80,000 to 99,000 pounds. 18 per cent. goes with 80,000 and 100,000 pounds, while 16 per cent. accompanies 85,000 and 103,000 pounds.

What causes this apparent anomaly?

Let us take the product of two different steel works, and if we test it in 8-inch section, the tensile strength and elongation may be found alike in both cases. Yet if we test the same steel with a 2- or 4-inch section we may find a difference of from 4,000 to 6,000 pounds per square inch, and several per cent. of elongation between the two products. Here we have not only a riddle, but a powerful argument why we need uniform methods of testing, and that it is in the interest of manufacturers as well as the engineer to bring about such uniformity.

Right in line with this puzzle is that other puzzle, shown first by Bauschinger and Wöhler, and confirmed since by numerous investigators, that removal of the load which is straining a piece of metal does not stop the activity of molecular motion in that piece, but that activity once aroused continues for days, weeks and months after the load has been removed. Thus, for instance, if a test-piece has been stretched somewhat beyond the limit of proportionality it will, on removal of the load, return partly to the original length at once. It will not stop there, however, but will continue to grow shorter for weeks and months, more rapidly at first, but slower and slower afterwards.

Having tried your patience with a recital of some of the riddles wrought in iron and steel across which the practical metallurgist stumbles every day, let us consider now some of the manifestations which apparently are the source of many of the riddles we come across.

To solve these riddles must be our constant endeavor if we are not to retrograde in the art of applied metallurgy and lose the advantages we have gained in our struggle for supremacy in the markets of the world.

One of the principal, though not the only, sources of the riddles we encounter in steel and other cast metals is, no doubt, that characteristic of alloys to segregate.

This tendency to segregate does not necessarily mean the formation of a nodule of same size within a shrinkage cavity of a chemical composition entirely different from the surrounding mass, or the lining of a shrinkage cavity with those pine-needlelike crystals so characteristic of iron alloys, nor yet of the formation of hard spots.

While all of these are common occurrences, yet we have to look for an explanation of some of the riddles wrought in steel to that kind of segregation which produces a chemical change in the whole mass of steel and makes itself felt by a change in the whole structure rather than in separate spots.

That eminent metallurgist, Freiherr Jüptner von Jornsdorf, in speaking of the problems we have to deal with in metallurgy, says:

"All accumulated experience points to the conclusion that in metals we are dealing with solutions, and that the various components are segregations, the nature of which depends, of course, on the various elements of which the solution is composed and the temperature at which these elements separate.

"That this process of separation on cooling varies according to the point of saturation of the solution is well known.

"In a concentrated solution a part of the dissolved elements segregate out at a decreasing temperature. On further cooling, still more of the elements segregate out, until, at a certain point of temperature and concentration, the remaining mother liquor, that is, the solvent and the dissolved elements solidify together without further segregation of the one or other element. * * * In practice this phenomenon may become complicated in so far that, for instance, a concentrated solution of the one or the other

element is present in the molten alloy. On cooling, the excess of this element segregates out, and the remainder, or mother liquor, represents a diluted solution.

"If now, on further cooling, part of the solvent segregates out, then it is conceivable that a reversal of the previous condition takes place, and the mother metal again becomes a concentrated solution."*

This short extract from that very interesting paper may give us an idea of the complexity of conditions and distribution of elements in cast iron and steel, due to their separating and segregating at different temperatures in ever-varying percentages.

Thus we can readily imagine the almost incomprehensible complexity of conditions, arising in a cooling mass of cast iron or steel, especially of cast iron, which is richest in divers elements, by the partial or complete absorption, saturation, equalization, segregation, exchange and interchange of the various elements, according to their affinity, the law of crystallization governing them, degree of melting heat and rate of cooling. In these reciprocal effects of absorption and segregation, of solution and saturation of the varying and ever variable elements composing cast iron and steel, complicated still more by the melting point and rate of cooling, we no doubt often may find the reasons for at least some of the riddles wrought in iron and steel. As we go down in the scale of temperatures from the highest degree of fluidity to the point of complete solidification we have a series of formations of groups of elements, the last of which decides the quality and usefulness of the metal.

Conversely, when heat is applied to a solidified mass of metal, the various groups of elements will not soften and melt simultaneously, but in succession, and herein we find the source of many riddles and complexities due to the heat treatment of steel.

It is, indeed, an indisputable fact that we can spoil a

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* Die nächsten Aufgaben der chemischen Untersuchung von Metallen, besonders von Eisen und Stahl.—*Baumaterialienkunde*, Heft 5 and 6, Bd. II, 1897.

good piece of steel by improper heat treatment and can improve an inferior grade of steel by proper heat treatment, and we can also produce different qualities in the same piece of steel by a judicious heat treatment.

Here, for instance, is a series of four microphotographs, each of which shows a different structure, as well as a different tensile strength and ductility, although the four pieces are one and the same piece of steel, having had exactly the same structure and physical qualities and chemical elements originally.

The photographs were made for the Franklin Institute by Mr. F. D. Maisch, of this city, from the piece of steel treated, and are seventy times magnified.

Fig. 1 is the original steel. Its tensile strength was 103,000 pounds per square inch and 15 per cent. elongation in 2 inches. We see by the dark, dense blotches and irregular structure that the steel was in a disturbed condition. The carbon was 0·4 per cent., and the high strength as well as the appearance and irregularity of structure for this grade of steel indicate internal strains.

The original piece having been cut into four pieces, piece No. 2 was heated to produce what the author considered normal axle steel. The result is seen in *Fig. 2*. The structure has become quite uniform and more open-grained than in *Fig. 1*. The tensile strength has fallen to 87,000 pounds per square inch, and 35 per cent. elongation in 2 inches, a decrease of 16,000 pounds per square inch and increase of 20 per cent. elongation.

A third piece was heated in a different, though not unusual way, when *Fig. 3* was obtained.

This brought the tensile strength down to 84,000 pounds per square inch and 22 per cent. elongation in 2 inches. The structure has become coarse, showing a distinct separation into two well-defined bodies of metal. The fall in strength and elongation indicate impaired quality of the steel, if we consider *Fig. 2* as the most suitable quality.

The fourth piece was then annealed to a high degree of heat and left to "soak" for two and one-half hours.

The result we see in *Fig. 4* when the strength had fallen

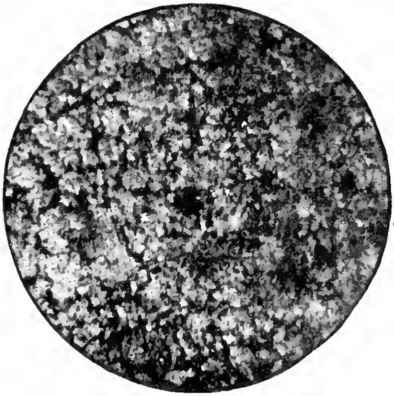


FIG. 1.

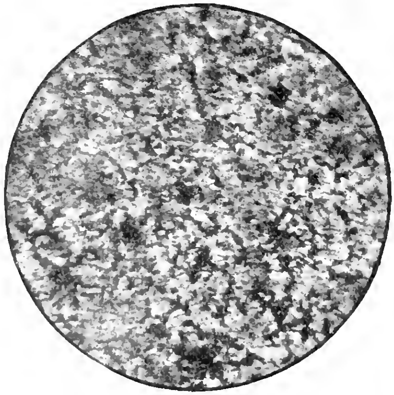


FIG. 2.

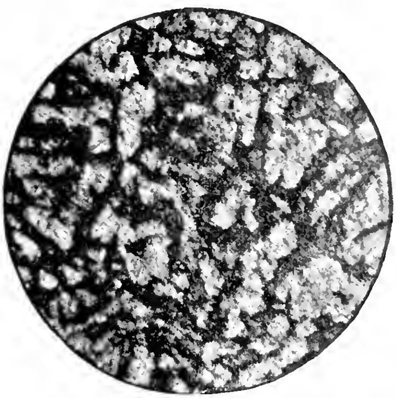


FIG. 3.

FIG. 4.

PHOTOMICROGRAPHS SHOWING CHANGES OF STRUCTURE IN SAME PIECE OF STEEL CAUSED BY DIFFERENT HEAT TREATMENT ($\times$ 70).

to 80,000 pounds per square inch and 20 per cent. elongation in 2 inches. The structure has changed radically, and clearly shows overheating.

Now let us suppose such varying degrees of heat or modifications of them are applied to the members composing a structure, or to the individual pieces of a lot or shipment, then we can readily imagine the almost endless variety of structures in the steel of perhaps a day's work, of comparatively uniform chemical composition, and, what is still more important, the ordinary specifications for tensile test may bring all these structures, good, bad and indifferent, within the limits of acceptance.

Do we need to wonder if we find riddles wrought into that metal?

Other instances could be given to show you how comparatively little we know yet about steel and how much there is yet to learn when we can produce at will a difference of 23,000 pounds per square inch of strength and 20 per cent. of elongation in the same piece of steel at the same time.

In another case, the author succeeded in producing a difference of 21,000 pounds.

In producing such differences hardening of the metal is not taken into consideration.

While our knowledge of the causes and effects of the action and reaction taking place in steel is as yet rather fragmentary, hence the riddles, yet we are beginning to grasp the underlying principles.

We know now that steel is an alloy in which a part of the elements is held in solution by the iron, while part is a mechanical mixture. We are beginning to learn that there is no stability between the relations of the various elements at each and every stage of the life of steel.

We are comprehending that iron and steel is not the rigid, immovable mass we were wont to consider these metals, that they are, in fact, like very sensitive creatures, liable to be influenced by changes of temperature, unwilling to be abused and ill-treated.

It is the degree of this changeability of steel which

to-day requires our closest attention and study, the condition under which it changes, the reasons why it changes and what changes make a given grade of steel suitable or unsuitable for a given purpose.

The want of this knowledge causes many phenomena to appear as riddles to us at present.

What we need to do now is to make use of the susceptibility of steel by changing its nature to our advantage in producing the most suitable quality, at one time, or, at another time, to secure greatest possible uniformity, not only in one piece, but in a number of pieces.

We must use the pyrometer more freely than we do now in order to be able to determine the proper temperature at which to anneal and to temper and to produce the same results uniformly at all times. We must discard thumb-rule and guesswork in the present treatment of steel, just as we have discarded thumb-rule and guesswork in mechanics.

We must study the microstructure of steel in its relation to physical qualities and chemical constituents.

We must find the best methods how to measure and determine the properties and qualities of steel.

The author is well aware of the practical difficulties of doing all this, but this should not hinder us from adapting our methods of testing and investigating the qualities of steel as closely to its nature as we know how and to the condition under which we use it.

At present we often follow the old beaten path without paying due attention to changes in economic conditions and our improved knowledge.

Some of the riddles we encounter in iron and steel are not riddles in the sense that they are indications of a perversity of these metals, but they are simply and solely due to our tendency to treat the physical properties of iron and steel as things which can be measured like their chemical constituents, in the chemist's balance, or conform themselves to every notion we may have about the manner and method in which these metals are finished, tested and worked.

Since we are beginning to learn what peculiar effects heat treatment has on steel, we must go a step further in our progress and determine the finishing heat, the tempering heat, the annealing heat, the quenching heat, with the aid of the pyrometer, for a given grade of steel. If we are satisfied with wide ranges of the qualities in steel, we may go on in the ways we have followed thus far.

But if we want to use our resources to greatest economical advantage and be tolerably sure what we are doing in order to be sure what we are getting, we must adapt the means to the end in proportion as we progress in our knowledge.

DISCUSSION.

MR. WM. R. WEBSTER:—No doubt Mr. Kreuzpointner could have given us very satisfactory explanations of his "Riddles Wrought in Iron and Steel," but preferred that they should be thoroughly discussed, and thus call attention to the necessity of improving the heat treatment of steel in its manufacture, and subsequent operations of working it in the shops, and the desirability of standard methods of testing. The points raised are well taken, and will, no doubt, bring out a full discussion and accomplish the ends aimed at.

Data bearing on many of the "riddles" can be found in the recent papers and discussion on the "Physics of Steel" before the American Institute of Mining Engineers. Segregation and its effects were then taken up, and the following is quoted from Mr. R. D. Hibbard's remarks:* "To guard against segregation in ingots the following precautions may be observed:

"(1) Cast ingots of the smallest practicable size.

"(2) Cast ingots of as cold steel as practicable.

"(3) Cast ingots as slowly as practicable.

"(4) If the ingots must be large, and segregation is very objectionable, then purer stock than is otherwise needed must be used, or allowance made to cut off from the top or out of the center, or both, enough steel to remove the parts containing the worst segregation.

*Proc. Am. Inst. Min'g Engs., xxiv, 1894.

"(5) The method mentioned above, of making what I have called incipient rising-steel, must, it would seem, give ingots free from segregation. The steel in the mould is constantly in motion until the moment of solidification, and the impurities have no opportunity to collect anywhere. This method being applicable to soft steel only, however, will give no assistance in overcoming segregation in large high-quality hard-steel ingots."

I will endeavor to give solutions, based on the heat treatment of steel, to some of these "riddles." Of course, the chemical composition of the steel must not be overlooked, as on it, in connection with its heat treatment and mechanical work, the quality of the material depends.

Regarding plates that have failed after several years of service, it is always a difficult matter to get at all the facts:

(1) Concerning the conditions of rolling.

(2) The tests made on the plates.

(3) The abuse they may have received in shop treatment.

(4) The abuse they may have received in service.

After failures of such material, when the chemical analysis does not explain the trouble, physical tests, both before and after annealing, will often throw much light on the subject. The examinations by the microscope are also of the greatest assistance. The piece of boiler plate which I have here is a very simple explanation of failures of this kind. This plate is of open-hearth steel; it passed both mill and shop inspection for chemical requirements, tension test, per cent. of elongation, and per cent. of reduction; yet in forming in the bending rolls for a 60-inch shell it broke through one of the punched holes to the edge of plate. Further examinations were then made of the plate, and nothing in the chemical analysis or tension tests, taken from the plate close to the fracture, would account for the trouble. My attention being called to the matter, I suggested that both cold and quench bends be made from pieces cut from this plate. The former failed, as shown by this piece, and the latter bent down flat, as shown by this piece. This proved that the whole trouble was in finishing

the plate, in rolling, at too high a finishing temperature. Further investigation showed that the cold bends had been omitted in the original testing of the plate. I would call attention to the importance of always making these cold bends, not relying on the quench bends alone.

The changes referred to by Mr. Kreuzpointner as occurring in a piece of steel when heated at one end are shown in this piece of steel, it being a modification of Mr. Metcalf's beautiful experiment, and shows in one fracture all of the changes referred to, the difference in the sizes of the grain being a record of the temperatures to which the steel was heated. While we may not know the true explanation of this change, or when it takes place, yet we do know how to produce it, how to restore it, and how to avoid it. In the present case the large grain was produced by overheating the end and allowing it to cool slowly; it can be restored by careful heat treatment in annealing; if work had been put on this piece of steel while it was still hot, and continued at a low enough temperature, the large grain would have been broken up and a fine-grained steel produced. All steels undergo these changes. Their susceptibility increases with the increase of carbon.

The physical results from steel of any given chemical composition depend, to a large extent, on the finishing temperature. In axles, this accounts for the same per cent. of elongation for different ultimate strengths, and for the different elongations for the same ultimate strengths. The tendency of too high finishing temperature is to reduce the ultimate strength and per cent. of elongation, while too low a finishing temperature tends to increase the ultimate strength and reduce the per cent. of elongation. A definite solution of this "riddle" could have been obtained by carefully annealing the axles and making additional tension tests. The changes produced by annealing depend upon the chemical composition of the steel and the former treatment it has received, as well as the temperature to which the steel is heated, time kept at that temperature, and manner of cooling. In all cases the steel should be allowed to cool before it is heated for annealing.

The temperature of steel remaining the same, or increasing for successive passes, is accounted for by the heavy reductions, in rolling, elongating the material, and bringing nearer to the surface quickly the hot interior of the slab; and by the heat generated in this work. The extent to which the heat generated by work can be carried is cited by Mr. Metcalf in his "Manual for Steel Users," in which he states: "A skilful hammerman will take a piece of mild, cold steel, and by means of light, rapid blows he will heat it up to a bright lemon heat without fracturing it; then he will have it thoroughly plastic and malleable."

The changes of structure noted above occur in wrought iron. I have known of iron eyebars being condemned for a coarse crystalline structure in the neck, no work having been put on the bar at that point when it was heated to form the head. Some of the manufacturers, in order to guard against this, annealed all of their iron eyebars. I further recall one lot of upset iron anchor bolts that on testing, full size, broke at the base of upset, showing a coarse crystalline structure, and after carefully annealing broke in the body of the bolt, showing a tough fibrous structure.

I have only referred to the direct effect of the heat treatment on the physical properties of the steel. Its effect on the form of the carbon present should not be overlooked in this discussion.

In considering heat treatment, its effect on cast iron must not be overlooked, as many of the changes in the structure of this metal are due to heat, and are closely related to the corresponding changes in steel. This is shown in many ways; for instance, from the same ladle of iron a fine grain is produced in a small casting and a large grain in a large casting, the difference depending on the composition of the metal to start with, temperature of metal when poured and difference between the sizes of the castings. Another way of stating this is that the grain in all cases depends on the chemical composition of the iron and its heat treatment.

The large casting holds the heat much longer and allows the large grain to form. This is proven by producing the

large grain in the small casting by keeping it at a high temperature and delaying the rate of cooling.

Those are the direct effects of heat, but there are also the corresponding changes in the form of carbon present.

One will naturally ask: can corresponding changes be made in iron castings, after they have cooled, by a simple heat treatment that does not change the total amount of the elements present?

This, no doubt, will be answered by Mr. Outerbridge and others who have had a great deal of experience in this line of work.

I would like to ask the following questions:

(1) Can white iron castings be changed to good gray iron by annealing? If so, what is the gain in strength over corresponding gray iron castings produced in the ordinary way?

(2) I would also like to know what changes can be produced in good gray iron castings by heat treatment alone.

In these questions I do not refer to any changes depending upon the total amount of carbon or other element present, for instance, by treatment with oxide of iron or other material, but merely to simple annealing (as generally understood for steel), in the first case, and heating and quenching in the second.

A. E. Outerbridge, Jr.:—The letter I received a few days ago from the Secretary of the Institute, relating to the special meeting called to discuss Mr. Kreuzpointner's paper, requested me "to take up such points as deal with cast iron and the behavior of molten metal."

There are riddles in cast iron as well as in steel, some of which will probably remain unsolved as long as the metal shall continue to be used, and I purpose making some statements regarding the behavior of cast iron when subjected to heat treatment which are, I believe, at variance with the current views, and are, therefore, open to criticism and correction should they be found not in accord with actual facts. I may say, in the first place, that there is a close analogy between the behavior of cast iron and steel, in some respects, when subjected to heat treatment, but in others there are much more radical differences of behavior

than our intimate knowledge of the composition of cast iron and steel would lead us to suspect.

Let us cite an instance where there is, evidently, a close analogy between cast iron and steel. If, for example, a bar of steel is heated to a certain temperature and suddenly quenched in cold water, it will become hard and more or less brittle. In like manner, if a bar of ordinary gray cast iron be heated to a certain degree (which may be called the "critical temperature") and suddenly cooled by immersion in a chemical solution of various salts, or even in cold water, it will become extremely hard, not merely upon the surface, but throughout the mass. I should, perhaps, explain that I do not now refer to so-called "chilled iron," *i. e.*, a metal in which the carbon and iron are in chemical union, having a characteristic crystalline structure and white color.

It is possible, in this simple manner, to change a comparatively soft gray iron casting into a metal as hard as steel; in fact, cutting tools for lathes and planers have been made of common gray cast iron thus hardened, not "chilled" on the cutting edge. The hardened bar of cast iron is very brittle and the fracture is much lighter in color than the original metal, closely resembling tool steel. Singularly enough, this fact does not seem to be universally known, yet this is one of the few instances in which cast iron and steel behave alike under similar conditions. But you may say, "What about the strengthening of cast iron by annealing; is there not a close analogy in this respect to steel?" I answer emphatically "No!"

It is, of course, very well known that some castings, such as chilled cast-iron car wheels, are greatly improved in strength by annealing in heated pits for a period of from three to five days, and from this fact it is generally assumed that annealing cast iron strengthens the metal. Nevertheless, I am prepared to make the positive statement—which may seem startling in view of the widespread belief to the contrary—that annealing gray cast iron by heat *invariably weakens the material.* How, then, can we explain the apparent anomaly that a cast-iron car wheel is strengthened by

heat annealing, if it be true that gray cast iron is invariably weakened by heat annealing? This is a riddle that may be readily solved.

A chilled cast-iron car wheel is subject to abnormal cooling strains due to the conditions under which it is cast. If a car wheel is allowed to cool in the air, like an ordinary casting, the cooling strains are sufficient to overcome the molecular cohesion of the metal and usually to cause the wheel to break asunder with a loud report; but if it is placed, while still red-hot, in an annealing pit and allowed to cool very slowly, these strains are gradually eliminated and the casting then becomes exceedingly strong. If now you ask, "Is the gray metal of which the plate of the wheel is made as strong after annealing as before?" I say, positively, it is not. Such a statement, however, to be convincing and to have practical value, must be accompanied by irrefragable proofs. Several years ago I made many experiments to ascertain the facts in the case, and very recently I have repeated some of these tests with entirely corroborative results.

Several bars of cast iron of various grades, ranging from soft pulley metal, having a tensile strength of about 18,000 or 20,000 pounds per square inch, up to very strong iron showing over 40,000 pounds tensile strength to the square inch (on bars of 1-inch section cast 30 inches long), have been made and tested, both before and after annealing, within the past few weeks. The *modus operandi* was as follows: The bars were first broken once upon a testing machine with supports 12 inches apart and the transverse strength of the unannealed metal was thus ascertained; one of the pieces of each bar was then turned in a lathe and pulled on a testing machine, thus the tensile strength of the unannealed bar was also determined. The remaining pieces of the bars were then placed in the annealing furnace and subjected to high heat for nine hours; the bars were then very slowly cooled while still enclosed in the annealing cases to protect them from the oxidizing effect of the air. The annealed pieces were then treated in precisely the same manner as were the unannealed pieces of

the same bars to ascertain the transverse and tensile strength. In every case the annealed bars were much weaker than the unannealed portions of the same bars. Two recent tests will suffice to illustrate this. Two bars 30 inches x 1 inch x 1 inch were poured from strong cast iron taken from a ladle holding about 8,000 pounds of molten metal and the following records obtained:

Transverse strength of bars not annealed.

No. 1 = 3,350 pounds (center load).
No. 2 = 3,300 " " "
Deflection No. 1 = ·1444 inch; No. 2 = ·1278 inch.

Transverse strength (same bars), annealed.

No. 1 = 2,700 pounds (center load).
No. 2 = 2,700 " " "
Deflection No. 1 = ·1556 inch; No. 2 = ·1333 inch.

Tensile strength (same bars), not annealed.

No. 1 = 37,285 pounds per square inch.
No. 2 = 36,072 " " " "

Tensile strength (same bars), annealed.

No. 1 = 24,500 pounds per square inch.
No. 2 = 24,500 " " " "

The fracture of the annealed bars shows much darker gray and somewhat coarser grain than the unannealed pieces of the same bars; this is due to the change of combined carbon to the graphitic form, and accounts, in part at least, for the weakening effect of annealing cast iron.

Not wishing to extend this discussion to an undue length, I will allude to but two other radical differences between cast iron and cast steel. There is comparatively little difference in the physical characteristics of the metal in a large or in a small casting poured from one ladle of molten steel, but there is a great difference in the character of gray cast iron when poured from one ladle into large and small castings. Furthermore, there is a lack of homogeneity in different parts of the same casting, causing wide variations in the physical properties of the iron. This was proved in a conclusive manner in some tests made twelve years ago, a brief account of which first appeared in print in the *Iron Trade*

Review, November 25, 1897, and as this article (written by the editor of that journal) also gave my views upon the effect of molecular vibration, or shock, on cast iron and steel, to which subject Mr. Kreuzpointner has alluded, I will close my remarks with a reference to the paper in the *Iron Trade Review* of the date mentioned.

"Reference was made in our issue of the 11th inst. to the report of the Committee of Science and Arts of the Franklin Institute, on the discoveries of Alex. E. Outerbridge, Jr., of Philadelphia, concerning the effect of shock or vibrations on cast iron. A table of tests appended to the report gives the results of independent experiments conducted by the committee. In some cases the gain in strength in bars tested by the committee by rumbling exceeded the maximum gain published in Mr. Outerbridge's tables, by more than 100 per cent. The largest gain claimed in Mr. Outerbridge's paper read at the Pittsburg meeting of the American Institute of Mining Engineers in February, 1896, was a little less than 19 per cent. The Franklin Institute Committee made its own bars and tests and obtained 40 per cent. gain in strength and 48 per cent. in deflection, as a maximum increase in the strength of a bar after it had been subjected to repeated shocks. In some cases bars which had been subjected to shocks in the barrel were found to be defective castings, yet they were stronger than companion pieces, free from defects, but not subjected to this treatment.

"The question has been raised whether a similar effect would be produced upon steel. Writing on this subject to the *Iron Trade Review*, Mr. Outerbridge says:

"'I have been frequently asked this question. I have always replied, 'No.' The conditions are radically different. 'Cooling strains' in cast iron must not be confounded with contraction of steel. The molecular structure of cast iron is determined by the rate of cooling quite as much as it is by the chemical constituents. A large casting and a small one from the same ladle of cast iron are unlike; with steel, however, no such great difference exists between large and small castings poured from one ladle.

"'Several years ago I had a solid block of cast iron 15 x 15 x 15 inches cut up into sixty-four test bars 1 inch square and 14 inches long, numbered and broken. There were eight rows of bars with eight bars in each row. The bars from the center of the block were coarse, open-grained metal, and the strength was scarcely more than one-half the strength of the bars from the outer section. There was a difference of nearly 40 pounds to the cubic foot in weight of the metal, as determined by specific gravity, between the comparatively close-grained, strong bars from the outer section and the open-grained bars from the interior. This explains, in part, at least, the tremendous cooling strains in cast iron, irrespective of the actual strength of metal, which can be relieved either by slow cooling, as in annealing a car wheel, or by continued vibrations of the metal while cold.

"'The large test block referred to above was made in 1888. The result of tabulating the breaking strains of the great number of bars cut from the block convinced me that the attempt to draw any conclusions regarding cast iron, as ordinarily employed, from the breaking strength, shrinkage, etc., of small bars, which are practically uniform in texture, or molecular structure—owing to quick cooling of the metal—would certainly lead to grave errors. Abundant proof of this has since been given to the world in various publications, and more, doubtless, is still to come.'"—*Iron Trade Review*, November 25, 1897.

In the foregoing remarks I have referred to the effect of heat treatment on gray iron exclusively, but Mr. Webster asks, "Can white iron castings be changed to good gray iron by annealing? If so, what is the gain in strength over corresponding gray iron castings produced in the ordinary way?"

In answer to this I would say that about twenty years ago the curious discovery was made that white iron, forming the hard wearing surface, or "tread," of some chilled cast-iron car wheels which had been accidentally overheated in an annealing pit, had been completely changed to soft, fine-grained, dark gray iron, by the heat treatment. No practical use was made of this discovery at

that time, but recently the principle has been applied commercially, with success, to the production of very strong gray iron castings. These castings are made originally of white iron, subsequently changed to the gray condition by annealing, and tests made by Riehlé Bros. of this converted gray cast iron show remarkably high tensile strength, ranging from 50,000 to 67,150 pounds per square inch. Axes, hatchets and other cutting tools are now made of white cast iron, then annealed to change them to gray iron (without decarbonizing, as in the malleableizing process) and subsequently hardened, on the cutting edge, by heating and sudden cooling. Such tools are now sold under the name of "steel castings," but this is, I think, clearly a misnomer. The metal is not steel, neither is it malleable iron, and it may be defined as a new commercial product standing between cast iron and steel, partaking somewhat of the qualities of each. In this process the heat treatment, or annealing, has changed a hard, brittle, white cast iron, only fit for sash weights, into an exceedinglys trong, fine-grained machinable metal, suitable for many valuable purposes and for which I think there is a wide field of usefulness in the future.

In reply to still another question of Mr. Webster, I would say that the grain, or texture, of gray iron in small castings may be very materially altered by slow cooling. For example, I have found by actual tests that light castings of thin section, made in a mould with a large casting, in close proximity thereto, will have more open grain and will be much softer than similar light castings poured in a separate mould from the same iron. There are other ways in which the same effect can be produced by prolonging the cooling of the metal in small castings, and in this way the necessity for annealing such light castings to make them more readily machinable may perhaps be obviated.

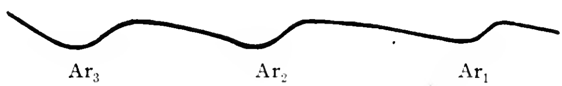
Mr. G. H. Clamer:—Modern metallography is rapidly solving the mysteries presented in the behavior of iron, steel and other alloys. By the aid of the microscope many facts have been discovered which chemistry could not account for. All iron carbon alloys show peculiar behaviors

under the influence of heat, and, if allowed to cool from a point above the melting point, will show at least one so-called critical point, at which degree of temperature a wonderful change takes place in the interchange of the contained elements or in their structural arrangement. For instance, very mild steel will show at least three such critical points, each indicative of an important change going on within the metal. A curve representing these changes would be as shown in *Fig. 1*.

A medium hard steel shows two such stops in the cooling curve, and the high carbon steels but one.

All steels, according to modern micrographic researches, are made up of at least two of the four primary structural components, which have been termed ferrite, pearlyte, cementite and martinsite.

Ferrite is iron free from carbon, but not necessarily free from other elements.



Pearlyte is a mechanical mixture or solid solution of ferrite and cementite.

Cementite is the carbide of iron Fe_3C. when it exists in segregated masses.

Martinsite—the true nature of which is not known—constitutes the hardening element in quenched steels.

When steel has been heated above the critical range, the constituents arrange, or perhaps combine, to form martinsite, and, if it be quenched before cooling down to the critical range, the point Ar_1 disappears altogether. On the other hand, all steels which have been slowly cooled below the critical range contain pearlyte and no martinsite. Steels above ·9 carbon (the saturation point of carbon and iron) contain cementite, whether quenched above Ar_1 or slowly cooled, the quenched steels consisting of martinsite and cementite, and the slowly cooled pieces, pearlyte and cementite; but never can pearlyte and martinsite occur together.

Steels below ·9 carbon, slowly cooled, consist of ferrite and pearlyte, whilst above ·9 carbon consist of pearlyte and cementite. Ferrite and cementite can never occur together.

With a knowledge of the above facts, which have established a basis for modern metallographic study of iron and steel, and the use of the pyrometer, I think many of the riddles which Mr. Kreuzpointner has pointed out could be satisfactorily solved.

MR. FRANCIS SCHUMANN called attention to the radical changes that had been introduced in modern practice in the annealing of glass. By the old method the time required for annealing large masses of glass varied from 56 to as much as 72 hours, and the results were not at all certain. By the modern methods lately introduced the annealing time is reduced to 45 minutes, and, with reasonable care, the results are uniformly good.

The conditions to be observed, he stated, are a tolerably high initial temperature of the mass to be annealed, and, especially, a uniform rate of cooling. In this last condition, the speaker said, lay the secret of success. The time occupied in cooling is found to be of little importance in affecting the quality of the results, but, whatever be the rapidity of the operation, the rate at which the successive decrements of heat take place must be as nearly absolutely uniform as possible to insure a successful result.

MR. ASA W. WHITNEY:—My experience has been in the regulation of mixtures for cast iron from the cupola, crucible and air furnace. The few problems to which I am prepared to direct your attention do not appear at first sight to have any bearing on the riddles of steel with which Mr. Kreuzpointner's paper is principally concerned, but when the great range of compositions included under the term Cast Iron is as fully investigated as is now the different range called Steel, these riddles, or problems with apparently insufficient data for their solution, will doubtless be solved as well as others have been for immediately practical purposes, thereby establishing more complete relations between cast iron and steel.

Referring to the weakening of the *metal* of cast-iron wheels by the annealing which strengthens the *wheels*, my similar tests on wheel iron bars some years ago confirm Mr. Outerbridge's statement. Moreover, the difference of ·05 to ·07 inch per foot between the contraction of the solid white chilled iron and of the solid gray iron of the casting gives some idea of the enormous strain which must be accommodated.

I have here a small specimen representing a class of phenomena in cast iron upon which Mr. Kreuzpointner's quotation on page 6 from Freiher Jüptner von Jornsdorf evidently bears. A casting from a mixture intended for soft light work, in this case about $\frac{5}{8}$ inch square, has a perfectly white core about $\frac{7}{16}$ inch square surrounded by a close, gray, moderately soft iron, the demarcation being very sharp. I have no analysis of this piece, but only recently Mr. W. J. Keep gives the following partial analysis of a very similar case ("Stratified Cast Iron," in *The Foundry*, December, 1899, p. 154):

	Gray Part.		White Part.	
Total Carbon,	3·628	comb. 1·754 graph. 1·874	3·861	comb. 2·554 graph. 1·307
Silicon . . .	2·846		2·742	
Manganese . .	—		·501	

In neither case are the phosphorus and the sulphur given, and the manganese is given only in the white part. Had the figures for these elements been furnished, the percentage of iron could then be found by "difference," as usual, for lack of a more exact method. Then there would have been something to figure upon, and we would have had a problem instead of a riddle. But as it stands, it is not a fair question or even a legitimate riddle, and certainly does not warrant Mr. Keep's answer, "The chemical analysis of an iron will not indicate its physical quality, and nothing will, except a physical test." I believe that study on a few complete analyses of such cases would soon discredit such off-hand statements, and show how a very small calculated change on the composition of the charged mixture would obviate such a trouble in castings in cases where a change of melting conditions would not be feasible.

In my contribution to the subject of cast iron in the Franklin Institute *Journal*, April, 1897, I gave some instances of this phenomenon in charcoal pig iron, with full analyses and a photogravure. The silicon in these cases was below ·2 per cent. in both the white and the gray parts. I also referred to its occurrence with silicon, about 2·5 per cent. In Mr. Keep's instance it is higher. What study I have put on this matter is in the relation of the iron and the carbon; with the result, so far, that in the white part the ratio, or possible compound, Fe_5C is more nearly approached than in the gray part in the same pig.

Mr. Keep's crucible remelt of the white part alone yielded a casting of light gray fracture. My crucible remelt of the whole low silicon pig made a casting with a far larger white and solid core, surrounded by gray iron, even in a ½-inch section. Having in mind the carbon and iron relation and the total oxidation, these apparently divergent results probably correspond.

The case of reversal of ordinary phenomena just cited is really but a step beyond this other case illustrated by these two solid white chilled iron samples of the same size on the table before you. One is finely crystalline, and may be easily drilled, while the other is nearly as coarse and fully as hard as spiegel, and from appearance iron experts have supposed its contents to be from 5 per cent. to 15 per cent. of manganese. Yet the manganese in the hard sample is but ·8 per cent., and in the soft one ·35 per cent., and the difference in other elements is also correspondingly small. This result was intentionally produced, just to show the great difference that very small but properly calculated variations on melting charges will effect, the other conditions being constant. A softer chill of another character could also be produced by other changes, the manganese remaining at ·8 per cent.

Just to indicate that many of the so-called riddles which are still under discussion in cast iron have already been commercially solved, I show here one of thirty-three sheets of a large graphical tabulation, arranged by Mr. Wm. R. Webster, in 1896, of physical and chemical results on test

bars of wheel metal of 4 square inches sectional area and 12 inches long. In the eighteen tests on this sheet, representing as many different heats, the variation in transverse strength is but 1·5 per cent. either way from the average of 58,500 pounds modulus of rupture (or 3,260 pounds on a 1-inch square bar 12 inches long). The variation in contraction is 7·5 per cent., and in resilience 12·3 per cent. from their respective averages. But the lines showing the amounts and variation of iron, carbon, silicon, manganese, phosphorus and sulphur seem to be wholly irregular, with the exception of the line joining the amounts of iron in these eighteen bars. This line shows an approximate relation to the strength. Had this tabulation been based upon the best results of mixtures made in the old way by reference to the physical tests of a small range of metal, some such range of chemical analyses would have resulted and no further argument would have been thought necessary to discourage any attempt to control mixtures by calculations on chemical analyses of a wide range of material of which no physical tests would be known.

But the latter method, including reference to melting conditions and to the physical tests of previous heats, and very rarely to analyses of the cast metal, has given me success in a great variety of mixtures ever since 1889. What is often referred to as a riddle in cast iron, namely, the fact that practically equivalent castings do not show the same analyses, has in my practice resolved itself into the almost daily problem of producing practically equivalent castings by so adjusting the melting charges by means of chemical calculation that a different but suitable chemical composition will result in the casting. This is far more practicable than to attempt to retain one composition with sufficient exactness in spite of changes in stock, and looked-for modifications of melting conditions. Though the method is often very laborious, the results exceed in certainty, quality and economy, those of the old method which attempts to avoid riddles and chooses to pay for being consumed by them.

Mr. H. V. Wille:—No doubt, as Mr. Webster has stated, Mr. Kreuzpointner himself could have solved the riddles enumerated in his paper, but it is nevertheless unfortunate that the title "riddles wrought in iron and steel" should have been selected. Such a title can only serve to perpetuate the erroneous idea of the mysterious nature of some of the failures of steel, the causes of which are well known; and such theories can only serve to discredit the most useful product of the century. It is only too true that theories of this nature have existed, and it is not surprising when we review the development of the iron industries with special reference to the determination of the properties of the product. Makers of iron became makers of steel, and it is natural that they should apply the same methods for gauging the qualities of the new product that were applied to the old, namely, tension and bending tests. It was not long before they learned that, in place of globules of pure iron incased in a covering of slag, they were dealing with a complex chemical compound, and it was found necessary to apply an additional measure of the quality of the product, namely, the determination of the chemical properties.

During recent years the size of forgings and thickness of plates have greatly increased, and the finishing temperature of the plates and forgings is consequently much above the average range of temperatures obtained on thinner and smaller plates, so that manufacturers and consumers are now learning that in the physical and chemical tests they only have two-thirds of the story, and that it is impossible to solve many of the metallurgical problems that come before them on these insufficient data. They are, therefore, confronted with the necessity of the establishment of microscopical laboratories. When such laboratories become more general and we have (1) the physical properties of steel as shown by tensile strength, elongation and reduction of area; (2) the chemical properties as shown by the analysis; (3) the structure as shown by the microscope, we will then have data that will enable us to trace the whole history of a piece of material, and we will be no longer confronted with such riddles as Mr. Kreuzpointner enumerates.

A plea has been made for uniform methods of testing. This is all very well, but for the purpose of solving "riddles" it is much more important to have a uniform system of records of tests. The larger number of steel mills keep an entirely separate record of their chemical and physical tests. If these two records were kept in parallel column it would be very much easier to trace a relation between the chemistry and physics of the steel. Certain results in tensile strength, elongation and reduction of area, when considered alone, may appear to be perfectly normal, but may be quite abnormal when considered in connection with the chemical analysis and dimensions of the piece from which the specimen was cut.

To illustrate the value of such a system, it is necessary to cite but one instance of its advantage. There is one manufacturing establishment that does not believe in "riddles," but insists that all failures in boiler plates are due to defective material or improper manipulation in the shop. If the material be defective, the plate is returned to the manufacturer; if the workmanship be at fault, the plate is charged to the workman. At the end of the first year, when the work was being summarized, it was noticed that 90 per cent. of the plates that failed in flanging had an extremely low manganese content, usually associated, in basic steel, with low phosphorus, and the cause of the trouble, namely, oxidation of the steel after the phosphorus had been almost completely eliminated, was at once suggested; the low manganese being due to the utilization of a large portion of this element in the partial reduction of the oxide of iron formed.

The necessity of annealing has been referred to by several speakers. On this phase of the subject it may be well to point out that general and indiscriminate annealing may do much more harm than good, because, unless the annealing is carried on with proper safeguards, and done under trained supervision, the danger of overheating or of improper cooling is greatly enhanced. The annealing temperature should be predetermined for each grade of steel, and a self-registering pyrometer should be used, so that if this temperature be exceeded those in charge will know. Unless

these safeguards are used it would be much better to dispense entirely with annealing, because the temperature of the piece as it leaves the hammer is more likely to be nearer to the desired temperature of a hit-or-miss annealing furnace. In addition to this, if the temperature of the annealing furnace be too high, usually a number of pieces will be injured, while if the finishing temperature be too high, usually only one piece will be injured. For these reasons, in the present state of the art, I believe that the unannealed product of the average forge is really, in general, better than the annealed.

The same statements apply in a modified form to castings. An instance recently came under my notice of cast-steel wheel centers that had been annealed.

A test piece of about 1 square inch area was attached to a spoke of about 8 square inches. When the test was cut off and pulled it gave an extremely low elongation, a fracture of a mealy appearance and the section cracked in various portions like dried cheese; but a test piece cut from the spoke itself gave a good elongation and a silky fracture. Here we have an instance of the small section of metal being overheated in annealing, whereas the large section was properly heated. This is an extreme instance, but it illustrates the danger one runs and the care that must be exercised in annealing complicated castings.

MR. KREUZPOINTNER:—The author regrets having been prevented by illness to personally take part in the discussion of his paper.

However, he desires to thank Mr. Webster for his confidence by saying the author could have given satisfactory explanation of his "Riddles Wrought in Iron and Steel." Of some of the riddles mentioned he might have been able to do so, of others he could neither give a satisfactory nor any explanation at all.

And because the author feels that he does not yet know all about iron and steel he put his paper in such a shape in order to give opportunity to others, better fitted in every respect than the author is, to enlighten the members of the Mining and Metallurgical Section and not hide their light under a bushel, as it were.

Mr. Webster very properly gives particular emphasis to the effects of heat treatment of iron and steel, especially the latter, and the writer cheerfully supports Mr. Webster by saying that, other things being equal, the best steel, of whatever grade, can be made, and only too often is made, an inferior article by improper heat treatment, while on the other hand an inferior steel can be made quite acceptable by proper heat treatment.

The reasons why are a riddle to the author, like many other phenomena about steel, however well acquainted we may be with the fact.

Whenever heat treatment of steel and its effects receive that careful attention which the importance of the subject deserves then there will be fewer riddles to be solved.

The author has followed with particular interest the remarks of Mr. Whitney, whose extensive metallurgical knowledge and experience give weight to whatever he says on the subject.

Mr. Whitney rightly perceives in segregation the disturbing factor which modifies, and too often nullifies, the best efforts of the moulder and founder. Not a few unsolved and unsolvable riddles in metallurgy are due to this phenomenon in a fluid mass of an alloy, like cast iron and steel, for its component parts to break up into groups on cooling, thus disturbing the homogeneity, and hence the uniformity of structure of a metal.

This subject of segregation offers a fertile field for study and experimentation.

Mr. Wille may be right in wishing the author to have selected another title for his paper. However, as long as engineering societies and scientific bodies find it profitable and necessary to discover and discuss the why and wherefore of certain metallurgical phenomena which persist in forcing themselves upon the engineer's and steelmaker's and founder's attention, often to their sorrow, the choice of title does not amount to much.

Steel is recognized nowadays as such a valuable and indispensable metal by the engineer that neither the few cocksure nor the excessively timid can affect its standing in the future.

The author has fought for steel, defended steel, pointed out its valuable properties and qualities and predicted its triumph over wrought iron many years ago at a time when many of its present admirers were either doubtful or directly opposed to the use of steel for purposes for which nothing else is used now.

Yet, notwithstanding there is hardly an engineer nowadays who would not use steel as a structural material for most purposes, we still have to learn a good deal about its properties and qualities, as Mr. Wille rightly points out, and the ever-increasing variety of purposes for which steel is used, and new or changed methods of production, forever opens new opportunities for necessary study and investigation, with consequent discussion.

Mr. Clamer's enthusiasm about the value of metallography is inspiring and well founded. There is no doubt scientific metallurgy owes a great deal to the microscope.

The practical usefulness can likewise hardly be gainsaid, provided the operator has the indispensable advantage of a never-failing source of all kinds of old, worn-out or broken, and new material of various descriptions for everlasting comparison. Then the work with the microscope can be made really useful. Metallography is too recent a science to enable us as yet to say what its final status will be in the realm of applied metallurgy.

While there seems to be no analogy between glass and steel, yet Mr. Schumann happily furnishes us with the analogy of certain properties of these widely different substances by calling our attention to the necessity of the slow and gradual cooling of annealed glass, which necessity applies with equal force to steel of all grades. Slow cooling of annealed steel is one of the essentials of proper annealing.

The author feels himself honored to be able to remark on the discussion of his paper by such a past master of practical metallurgy, notably of cast iron, as is Mr. Outerbridge, Jr. How well Mr. Outerbridge has mastered the intricate properties of cast iron is shown by his pointing out that the releasing from its casting strains of an iron casting does not necessarily mean a strengthening of the cohesive force

which holds the particles together, nor a hardening of the individual particles, or crystals.

An unannealed car-wheel would not be safe, though the individual particles may be harder and more unyielding than those of an annealed wheel. But the percentage of elements in cast iron, other than pure iron, are considerable, and the changing of their form, due to the annealing, probably tends to loosen not only the cohesion between the particles, but, by deduction, also softens the latter.

This larger percentage of foreign elements in cast iron over cast steel is very likely also the cause of the fact that the size of an iron casting has a great deal to do with its final quality and suitableness for the purpose intended, while the absence of the largest percentage in cast steel of the foreign elements found in cast iron eliminates this marked difference between large and small castings, as found in cast iron.

Altogether, it appears to the author as if the discussion had emphasized the need for future study of the heat-treatment of steel, of the value of uniform methods of testing, of the use of the microscope, and of segregation.

ELECTRICAL SECTION.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

(*Continued from p. 298.*)

THE WIDENED FIELD OF LAMP USE, ETC.

An entirely new and broad field was opened to lighting with the birth of electric light. Previously there was merely light—with electricity came illumination. Before the dynamo, light was used simply for necessity—hand in hand with the incandescent bulb came lighting for display, for ornament, for attractive effects.

The beautiful lighting display of the World's Fair, or more recently of the Omaha Exposition (the latter the most beautiful and best example of incandescent illumination the world has ever known), are a development and result made possible only with the electric light.

The adaptability of electric light and the special effects and results possible produced numbers of special applications which are well illustrated in lamps by the numerous special types now available. The first lamps were simple, plain multiple lighting lamps of about 13 candle-power. The first extension was into other candle-powers, such as the 32, the 50, the 100 and 150 and even 300 candle-power. Then the coloring and frosting of the glass gave a variety of effects. Next followed the miniature lamps. The first of these were battery lamps, made in 1883, for decorative lighting, at a Vanderbilt ball in New York. A large field was opened with this type. We now have the surgical lamp used to illuminate the interior of a person's anatomy, the dental lamp, the microscope lamp, the kinetoscope lamp, the bicycle lamp, the miner's lamp, the railway carriage lamp, and among the latest applications, the automobile lamp and the telephone lamp. This last is of special interest, and reveals the adaptability of the lamp to new purposes. To replace the sound or ear signal in telephone exchanges by the visual signal of a lighted lamp is a most original and valuable idea. These battery lamps are made in all shapes and sizes, pear-shaped, spherical and flat, from the size of the standard 16 candle down to the pea lamp, no larger than a fair-sized pea—in candle-power from $\frac{1}{4}$ of a candle to 24 candles, in voltage from 3 to 45 volts, and in economy from $2\frac{1}{2}$ watts per candle to 6 watts.

The unique character of miniature battery lamps for interior decorative effects prompted the production of miniature lamps that could be burned on the regular lighting circuits. These were produced to burn in series. These are what are called the series miniature lamps, and are most widely used for candelabra lighting, for electric signs and for decorative effects, for interior and out-of-doors, among

flowers and shrubbery, where a large number of units of light covering a large area are desired. The theatrical lamp, used for special stage effects and decorating dancers, is one of this class. They run in candle-power from 1 to 10 candle-power, and in various shapes, the twisted flame effect, the tubular, conical, bean-shaped and pear-shaped.

Series lamps, burning on regular lighting circuits, have of late years been a thorn in the side of the underwriters, and their rules and restrictions have resulted in the production of candelabra and miniature lamps adapted to burn in multiple on regular 100–125-volt circuits. This was quite an achievement in lamp manufacture, for many years considered impossible. Such lamps are in successful use, and to-day they have enlarged the field and application of miniature lamps and sign lighting.

A bank of incandescent lamps has always served as an excellent form of resistance. This has resulted in the production of the resistance lamp, a type largely used in connection with telegraph work. They are made of any desired resistance up to 1,000 ohms cold resistance for use with moderate currents, and are placed in tubular bulbs so as to minimize space. The desirability of having a lamp that could be turned down brought out the Edison night lamp, in which two filaments burn in series to give a dim light of about 1 candle. By the turn of a small thumbscrew, one of these filaments is cut out and the other burns at full 16 candle-power.

For stereopticon work the incandescent lamp is particularly well suited. A special lamp has been designed for this work, having a compact filament wound so as to make as near as possible a center or point of light. These are made standard at 50 candle-power, but higher candle-powers are obtainable.

For examining cask interiors, brewers and barrel cleaners require a long thin lamp that they may thrust through the bunghole and light up the interior of a cask. Hence the tubular or bunghole lamp, which is useful for confined or narrow places. It has recently been adapted with con-

siderable success for lighting the interior of counter show-cases.

In decorative work, lighting show windows, etc., a short bulb is frequently desirable, and this has produced the round bulb type.

The buoys of New York Harbor are lighted by electricity, and for this work a special type of lamp was devised with permanent wire connections made through a water-tight dummy base.

The United States navy requires a number of special types. All the regular Navy Cruiser lamps are 80 volts, and in special shaped bulbs. Then there is the navy signal lamp, a small lamp designed for quick lighting and extinguishing for signal work at night; also the torpedo lamp, instrument lamp and binnacle lamp. Unique and most interesting is the navy diving lamp, for use under water by divers. This is made of specially heavy thick glass, and protected from any damage from water or shock.

The European lamps are made in much smaller bulbs than are standard lamps in this country, so for the foreign trade a new lot of specialties are required.

The adoption of electricity for street railways has made a large demand for a type of lamp suitable for car lighting and running in series on the 500-volt railway circuit.

One of the latest and most interesting lamp specialties is the reflector lamp. This is made in a pumpkin-shaped bulb, of which the top side is covered with a silvered coating forming a perfect reflector. This makes a lamp of special value for a reading or desk lamp, or wherever the use of reflectors is required. The candle-power is concentrated in one direction to a threefold degree. Thus a normal 16 candle-power lamp in this special type will give about 50 candle-power in a downward direction.

Let us sum up and see how many varieties of lamps are required from the lamp manufacturer to-day.

In regular multiple lamps we have nine different candle-powers, and three different economies, and at least six different bases. Here are 162 types. In voltages we have

at least fifty regular types, which multiplies the number of types to 8,100.

These may be frosted, or any color—red, blue, green, amber or opal, which multiplies results by six, giving 48,600 types,	48,600
Now taking the Round Bulb we find varieties are	21,000
The tubular	21,000
Stereopticon	900
Resistance lamp (at least)	1,000
Multiple candelabra	500
Series candelabra	500
Special series (about)	500
Regular battery	40,000
Special battery (at least)	500
Navy lamps (about)	100
Foreign lamps (about)	10,000
Reflector lamp (about)	2,000
Night lamp (about)	400
Series lamps for alternating and arc circuit	100
Total	147,100

From the above we see the immense increase of types caused by the specializing of any one feature; for example, a special bulb, a special shape of filament, or a special efficiency. In regular multiple lighting lamps, we add a thousand or more types with each change to specials.

BETTER UNDERSTANDING OF LAMPS, ETC.

In early days the consideration for a lamp was simply that it should burn—the longer the better (so it was considered), irrespective of how much loss of light the lamp had suffered. No questions were asked as to the correctness or variation of candle-power or the limits of power consumed—in fact, the irregular voltage and absence of meters rendered it comparatively unimportant.

The first subject on which customers sought information was the power consumed by the lamp. A great amount of attention was directed to this feature, on account of the fact that dynamos were rated and sold by the number of lamps they could serve, and therefore a high economy lamp helped to increase the capacity of every dynamo. With

the introduction of the 3-watt lamp the question of mere initial efficiency became paramount. The real important feature, the amount of light given by a lamp, was, however, ignored or considered only in connection with its initial rating.

The manager of one of the large Edison stations actually stated, several years since, that he refused to believe his lamps ever changed in candle-power.

It is singular, when we consider it, how long it has taken lighting companies to understand the real essentials of a lamp. For years lamps were used as mere power-consuming devices—the light they gave was a secondary consideration. Some attention was called to the fact that lamps lost in candle-power while in service, but little heed was paid thereto. Many thought it a ruse on the manufacturer's part to dispose of more lamps, or if any considered subject at all seriously, they concluded it was a slight matter at most and decided to leave bad enough alone.

It has taken years to bring home the real considerations to electric lighting companies. These considerations are that a lamp is primarily designed and used to give light—that lighting companies are in the business of making and selling light, not power—and that the lamp is the chief essential of the lighting system.

Perhaps much of the blame for this lack of understanding can be laid to gas practice. Electric lighting has very naturally followed the principles and practice of the gas business. Gas fixtures and burners were supplied by the consumer, hence in electric lighting lamps should likewise be supplied, *i. e.*, purchased and renewed by the consumer. Gas tips were replaced only when broken, hence electric lamps should be used until they were burned out. The error of thus paralleling gas practice becomes evident when the difference in the conditions affecting each business is considered. In the gas business the quality and character of the light is dependent upon the quality of the gas—the old burner or tip (so long as it was not fouled) did not affect the result, and as these tips suffered little or no deterioration, there was no need of ever replacing them.

Mark the difference in the case of the electric light. Here the quality of the light (with voltage uniform) is not dependent upon the current—but upon the burner, *i. e.*, the lamp. Lamps upon the same circuit can be found that give markedly different results in light; moreover, the same lamp under same voltage will, when old, give but a fraction of the light it gave when new. These are well-attested facts, which clearly show that much in electric lighting depends upon the burner and in gas practically nothing. Hence, what might be good practice for gas is entirely wrong for electric lighting.

Recognition of these principles has caused the leading electric light companies to make the lamp a part of the apparatus owned and installed by the station. They have taken lamps out of the hands of the customer and supply all that are used on a free renewal basis. This prevents the customer from depreciating results and balking the efforts of the central station management to give a good service, as poor lighting is an inevitable result where the customer buys and renews his lamps.

This is one reason why electric lighting in the United States is so much in advance of the service abroad. In continental Europe the lamps are peddled out to customers of lighting companies by hardware stores, chandler shops and such. This not only renders a poor lighting service, but retards improvement in the art of lamp making. Under such conditions of supply and use of lamps, the lamp that is the cheapest and that will last longest is prized. This is almost invariably the lowest grade of lamp, and there exists, therefore, no incentive to the manufacturer to advance in his art. Relegating lamps to the hands of the customer always puts a ban upon quality. The control and supply of lamps by the lighting station on the contrary puts a premium upon quality. It is this excellent, wise and far-seeing policy on the part of the leading companies of the United States which has advanced their electric service and development beyond all other countries, and has aided the American manufacturer to produce an incandescent lamp that surpasses any in the world.

Nevertheless, knowledge of lamp essentials and correct use is not as widespread as it should be in the United States. There are hundreds of lighting companies in all parts of the country who are ignorant of or indifferent to a proper understanding of the subject. They will properly attend to the repair of boilers, engines or dynamos and all apparatus but that of the lamps, forgetting that the deterioration of the latter affects their service more noticeably and directly than any other cause. Enormous as is the consumption of lamps to-day, it is not half as large as it should be or would be were the proper and economical use of lamps observed by all lighting plants.

At the present low price of lamps, the cost of 600 hours to 1,000 hours of service is from eight to ten times the value of the lamp, and renders it economical, therefore, to the highest degree to use the highest efficiency possible and replace lamps frequently, since it is evident that the value of the current consumed by the lamp soon eats up the value of several lamps.

Byron says:

> "Better five hundred hours of glorious life
> Than a thousand dimly lit . . ."

and this is the ethics of lamp economy and service to-day.

Numbers of papers and discussions have treated on the subject of the lamp efficiency most economical for a given set of conditions and of the most economical life of lamps. All such discussions have their value, but the difficulty of applying formulæ to the varied and constantly changing conditions of different stations has limited their adoption in practice.

The present method is to follow a few simple rules formulated from the limiting conditions of practice.

The general rule as to efficiency of lamps is to use the highest practical efficiency suitable to the regulation. This gives the maximum station capacity in number of lamps and minimum cost of light to public.

As regards life, the leading practice is to limit the service of lamps to what is called their useful life. The useful life

is the period of time a lamp burns until it loses 20 per cent. of its candle-power—for example, the time required by a 16 candle-power lamp to drop to $12\frac{8}{10}$ candle-power.

This period is known for any given economy or make of lamp averaging to-day above 400 hours for the best 3·1-watt 100–125-volt lamps. The practical service method then is to renew lamps frequently enough to keep the average life within this limiting number of hours.

By periodical renewals of lamps on this basis the lighting service is kept as clean and bright as a room that is regularly swept and cleaned.

ADVANCE IN METHODS OF LAMP TESTING.

A correct understanding of lamps is obtainable chiefly through correct methods of test, and it is therefore of highest importance that the principles of correct testing should be thoroughly known and carefully observed. This is rendered still more important when we consider the numerous chances for error possible in the testing of lamps. There is hardly any practical testing work where persons with the best intentions but not thoroughly conversant with the subject are as apt to obtain discordant or misleading results.

It is gratifying to observe the growth of understanding on this subject, especially in the last two or three years.

Not more than eight years ago a paper was read before the Institute of Electrical Engineers giving an account of a lamp test as then conducted. It throws an interesting light on the lack of understanding thereon. In this test lamps of varied efficiencies running from $3\frac{1}{2}$ to $4\frac{1}{2}$ watts per candle were compared with one another in a life test without any allowance being made for this variation of efficiency. Further, results were considered chiefly as affecting the life of the lamps, and, although candle-power readings were taken, they were not reduced to percentages or any proper comparative basis.

This was on a footing with testing a lot of ropes of varying diameters by loading them all with the same weight and choosing those ropes as best that failed to break, irre-

spective of size of their diameter. In another instance a prominent professor of electrical engineering attempted to prove the value of so-called improvement in exhaustion by comparing 32 candle-power, 50-volt lamps thus exhausted with 16 candle-power, 100-volt lamps made in regular way. As a 32 candle-power lamp is naturally better than 16 candle-power, and likewise 50 volts better than 100, the error of this course becomes evident at once.

I desire to conclude this paper by a discussion of some of the features of lamp-testing, the latest methods of test, methods of determining and comparing the values of lamps and say a few words in regard to specifications and guarantees.

A lamp test can be said to be conclusive only when (1) the average product of each manufacturer is taken, and not specially selected lamps; (2) when a sufficient number of lamps are tested to secure a correct average result; (3) when the principles of correct testing are carefully observed, and (4) when the test is continued long enough to bring out the qualities of a lamp.

Modern methods of test cover three general features:

The physical examination for vacuum, defects in filament, and mechanical parts of the lamp.

The initial test for correctness of rating in candle-power and wattage at the rated voltage.

The life and candle-power performance test.

It is strange that the first two of these features of test were never formerly used. They are as necessary as the physical examination of the soldier to determine fitness for duty.

A lamp that cannot pass muster under physical requirements should never be accepted.

The effects of poor vacuum or of defective filaments are vital and far-reaching. Their elimination, therefore, becomes of the highest importance.

Poor vacuum results in the production of what are known as slumpers, *i. e.*, lamps that decline in candle-power rapidly and within a few hours—a most objectionable type. The test for vacuum is made with an induction coil drawing

about a $\frac{3}{8}$-inch spark. By touching the base of the lamp to one of the secondary terminals of this coil a glow or fluorescence is caused inside the lamp. A well-exhausted lamp will either show no glow at all, or a slight flash or fluorescence.

Filaments are subject to a defect known as spots. This is a thin spot or a point of high resistance in the filament. By burning the lamp dull red these spots are seen very distinctly. This spot is a weakness in the carbon and will cause it to burn out. Spots, therefore, are very serious faults, as they cause early breakage and shorten the life of lamps. Tests for this defect can readily be made by burning the lamps two in series. The spots will show up as bright points against the dull red of the filament.

Another serious fault in filaments is discolored carbons. A good treated carbon has a uniformly bright, shiny steel gray surface over its entire length. A discolored carbon shows up a sooty black or brownish oily-looking surface, either partly or wholly covering the filament. Such discoloration causes a rapid loss of candle-power, a most undesirable result. They can be detected by an eye examination of the filament by light (filament not burning).

In some makes of lamps tested the percentage of physical faults has been found to be over 100 per cent. Numbers of barrels of different makes tested showed an average of fifty lamps to the barrel with discolored carbons. In another make thirty-two lamps with bad vacuum were found in one barrel.

The value of a physical inspection is unquestionable. It is also a ready means for the early detection of the incompetent or careless manufacturer and the rejection of poor lamps, thus saving time and trouble of any further test.

It should be an invariable rule in the purchase of lamps to reject any lot, samples from which are shown on test to contain 10 per cent. of any of these defects.

CORRECT INITIAL RATING OF CANDLE-POWER AND WATTAGE.

The value of close and uniform rating has only been appreciated in recent years. Of course it was not desired to

have lamps very low in candle-power, but no objection was made as long as the variation was not more than the eye could detect (about 3 or 4 candle-power). For lamps to run high in candle-power was by many considered as very desirable, and one manufacturer used to urge it as an advantage with his lamps that his 16 candle-power lamps gave more light than any other, and there was no doubt about it; some of his 16 candle-power lamps ran as high as 30 candle-power.

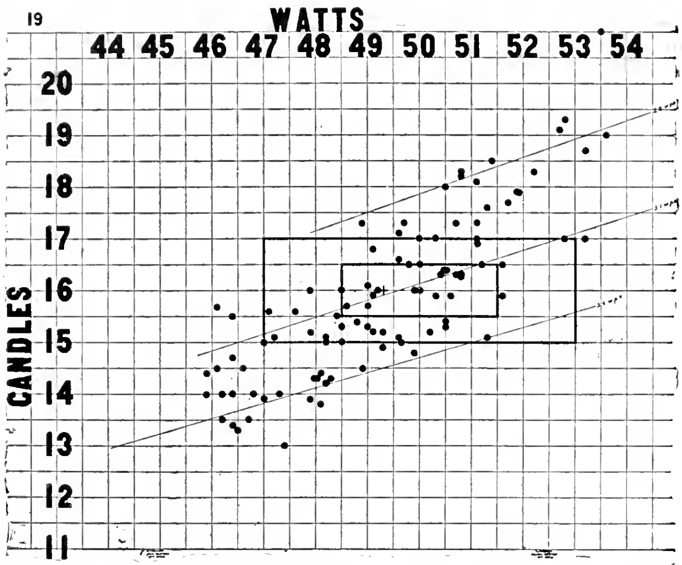


FIG. 2.—Target diagram showing initial measurements at marked voltage of 100 lamps, rated as 16 candle-power, 50-watt lamps.

For many years lamps were selected for watts, but the candle-power was allowed to wander over a considerable range. As the only testing instrument generally available was a wattmeter, skimping in candle-power passed unnoticed. This resulted in selling lamps for one efficiency which were really of a much lower efficiency, and there was no end of false conclusions.

With the introduction of the photometer, especially the portable photometer, most of this trouble ceased.

The importance of a close and uniform rating is very

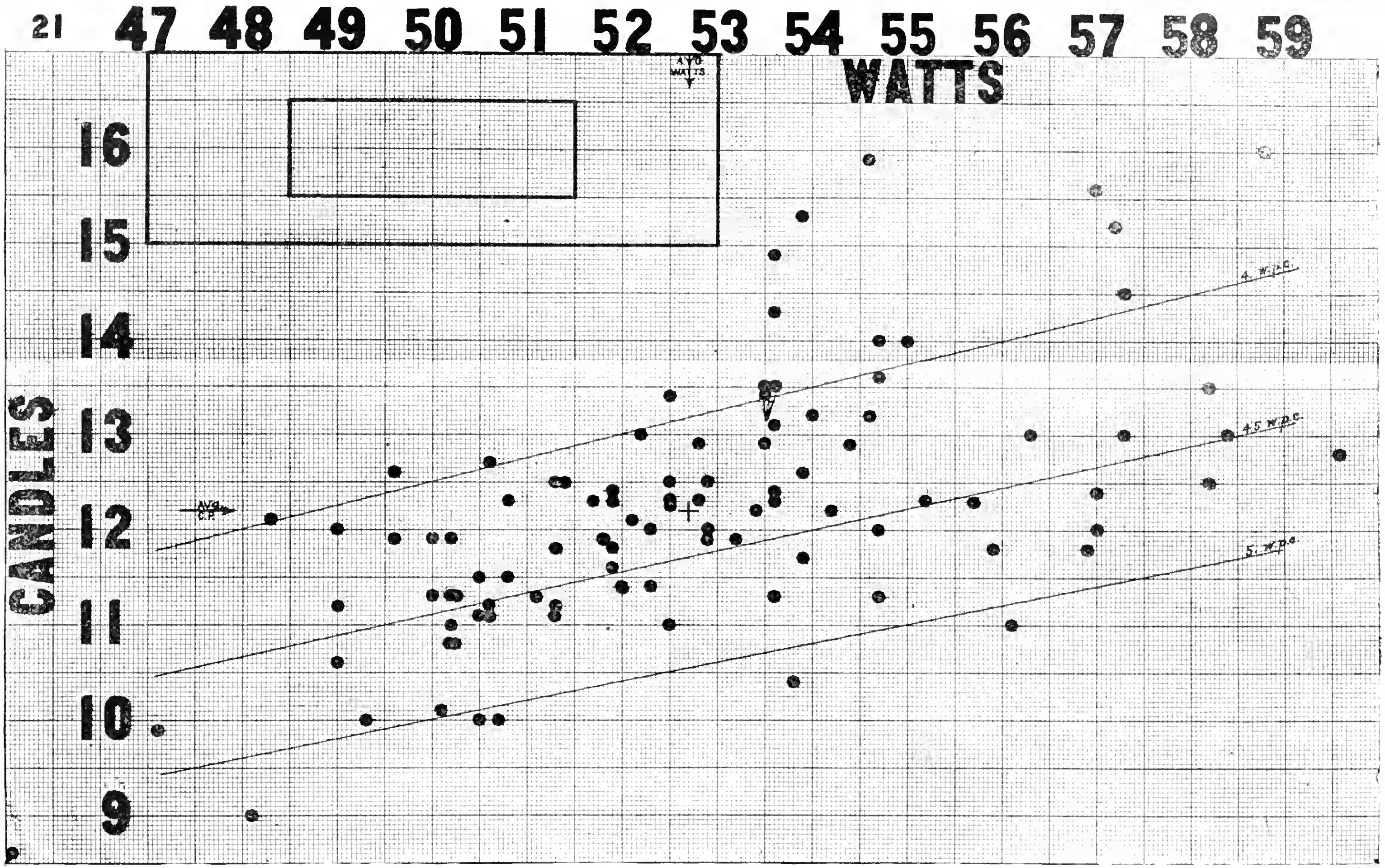


FIG. 3.—Target diagram showing initial measurements at marked voltage of 100 lamps rated as 16 candle-power, 50-watt lamps, illustrating very inaccurate rating.

great. We can consider the value of it in a more interesting way by an examination of some results of initial tests.

A very clever way has been devised of diagraming the results of initial test. (See *Figs. 2, 3* and *4*.) This is called the target diagram method. By plotting the candle-power as ordinates and the watts as abscissæ, we have a graphic means of delineating accurate marksmanship (or the absence of it) in lamp manufacture. The center of diagram, or bull's eye, is made the intersection of the 16 candle-power line, and the 50-watt line (in case of 16 candle-power 3·1-watt lamps). The readings taken upon each lamp of a lot tested are plotted by placing a dot at the intersection of the corresponding candle-power and watts line, and in this way the entire number tested are plotted. The rectangle drawn shows the limiting specifications for good lamps. The diagonal lines shown give the watts per candle.

The diagram, *Fig. 2*, gives the result of an initial test on 100 lamps, which were sold for 16 candle-power 50-watt lamps at 116 volts. The lamps average about right in candle-power and watts, but scatter considerably outside the limiting rectangle. In *Fig. 3* we have 100 more of the same make of lamps. The difference between these two lots is that this last is a lot purchased in the open market, while the former lot was a special one direct from the manufacturer. This illustrates the difference between special and regular lamps, and the need of the precaution in regard to securing the average product for a test. An examination of diagram, *Fig. 3*, will serve to show the value of correct and uniform rating.

First—In candle-power we have a range of from nine candles to sixteen candles, an extreme difference equal to one-half of the rated candle-power. With such contrasts as this between lamps in service, the result will be, inevitably, bad lighting and complaints from customers.

Second—In watts we find a range from 47 to 60 watts. This means trouble for the meter man, and complaints from customers. There are over a dozen lamps in this lot taking from 15 to 20 per cent. more power than their rating calls for.

Third—In efficiency we note the lamps rated as 3·1-watt

lamps have a real efficiency of $4\frac{1}{2}$ watts. This shows the reduction in efficiency, resulting from low candle-power. Such lamps if measured for wattage would probably pass as 3·1-watt lamps, but when candle-power measurements are made the real watts per candle are shown to be $4\frac{1}{2}$. In a number of other cases of lamps incorrectly rated, lamps have been found to run high in candle-power, which is as grave a defect as running under candle-power. Lamps that run high in candle-power will be naturally strained at a higher efficiency than lamps nominally and correctly rated. Candle-power performance and service of these lamps will, therefore, be as erratic and non-uniform as is their initial rating. The heavy decline in candle-power due to incorrectly rated lamps

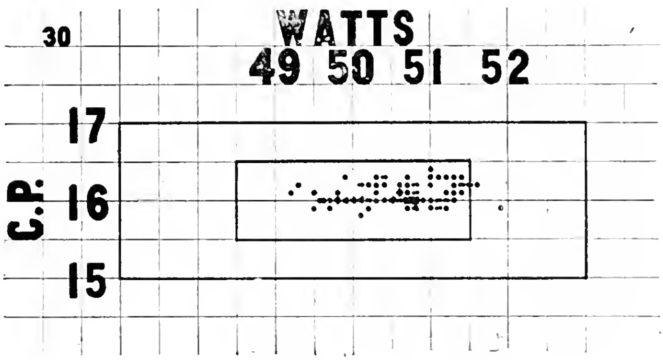


FIG. 4.—Target diagram showing results of correctly rated lamps.

(running high in candle-power) is well shown in diagram, *Fig. 5*, which gives performance of a number of lamps (rated as 16 candle-power) giving maximum candle-power readings.

Thus in a threefold degree is close and uniform rating necessary if we desire to secure good life and the best service results. It takes experience and ability to make lamps correct and uniform, and it costs money to select them to their close limits. Any attempt here to save money by the manufacturer would add greatly to the cost of renewals to the purchaser. It is, therefore, money saved for the purchaser to pay for these essentials, that is, purchase from the competent and capable manufacturer.

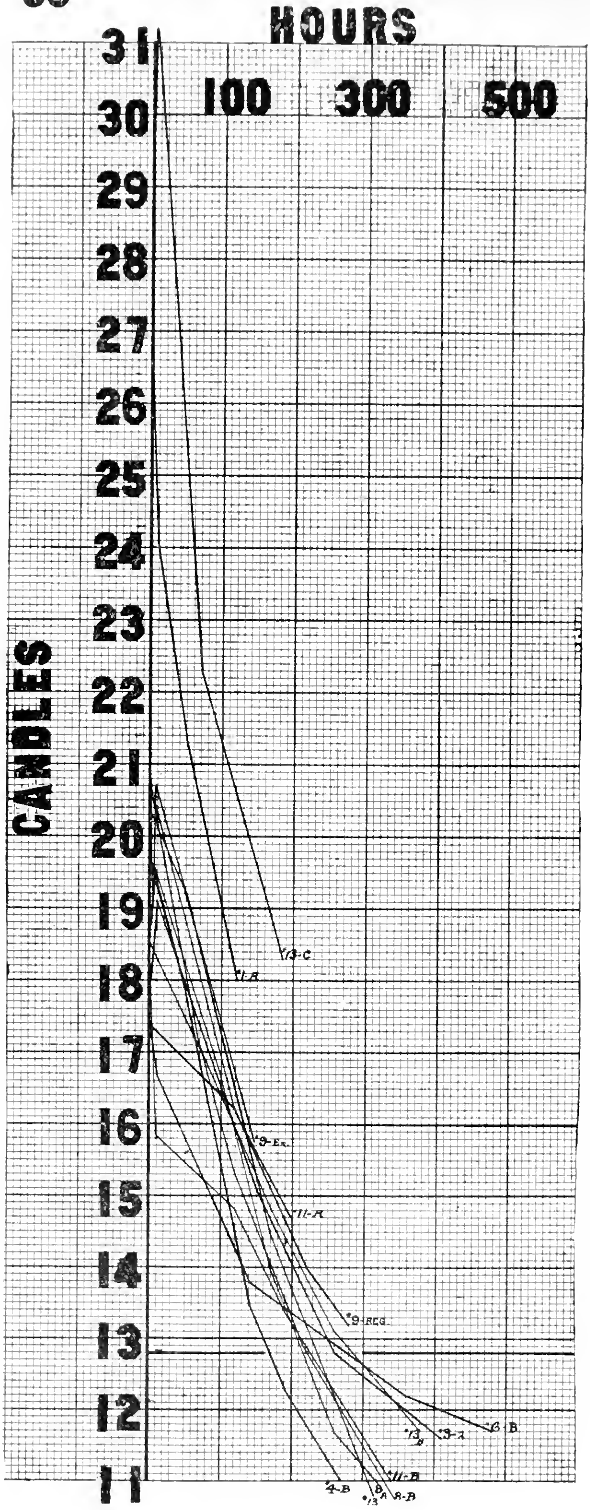


FIG. 5.—Showing rapid decline in candle-power of lamps measuring high in candle-power—well above their nominal rating.

Diagram, *Fig. 4*, shows the results of test on 100 lamps of a high-grade lamp, and illustrates what may be expected of well-made lamps.

It is to the interest of all purchasers to require lamps to conform to the one candle, 3-watt limits referred to above, by testing samples from each lot purchased, and rejecting every lot failing of these requirements.

There is no need of farther testing any lamps that fail in this respect.

In comparative tests of lamps, as many lamps as possible should be tested for initial rating—from 50 to 100 or more. This gives a full average of results, and besides provides a sufficient quantity from which to choose lamps of the efficiency taken as a basis for the candle-power performance test.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held January 16, 1900.

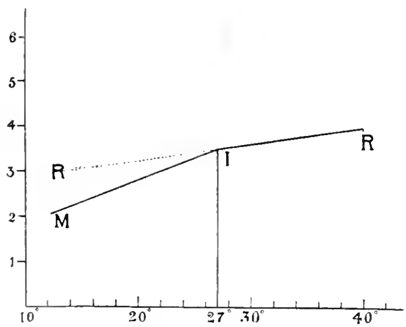
RACEMISM.

BY ROBERT HART BRADBURY.

(*Concluded from page 314.*)

Summing up, then, the equilibrium between the two antimeres, the racemic compound and their saturated solution is very much the same as that between two single salts, their double salt and the solution, and the phase rule applies to it in all its fruitful simplicity. The inversion point is the point at which the liquid in equilibrium with the racemic form as solid phase has the same composition as that in equilibrium with the mixture of the antimeres, *i. e.*, it is the temperature at which the solubilities are the same. Or it is the temperature at which the solubility curves for the mixture and for the compound intersect.

The diagram, borrowed from Van't Hoff,* represents the case of sodium ammonium racemate. The abscissas are temperatures and the ordinates concentrations expressed in molecular weights in 100 molecular weights of water. MI is the solubility curve of the mixture of the single tartrates. So far as this curve is concerned, the quantity of the tartrates in the solid mixture is a matter of indifference. The only condition is that they must both be present as solid phases. RI is the solubility curve of the pure racemic compound below 27°. Since the solubility of the racemate is greater than that of the mixture, it is clear that up to 27° the solution of the former is supersaturated with respect to



Solubility curves of sodium ammonium racemate and of the mixture of the two tartrates.

the latter. In this part of the curve the addition of the solid mixture will cause the crystallization of both antimeres from the solution of the racemate. I is the inversion point. Here the two curves intersect and here both solutions contain about 3·5 molecular weights of each antimere, the temperature being 27°. If we imagine the curve MI prolonged through I, it will evidently be above RI and be unstable with respect to it in exactly the same way as RI is unstable with respect to MI below the inversion point, that is, the addition of the solid racemate to the saturated solution of the mixture will produce crystallization of the

* "Bildung und Spaltung von Doppelsalzen," p. 83 (1897).

racemate, until the point corresponding to that temperature on the curve RI is reached. Thus the reversal of stability which occurs at the inversion point is entirely a matter of solubility and the whole phenomenon will be altered by the use of some other liquid in which the solubilities of the enantiomorphs and the racemic form are different.

The curve IR ends to the right in another transformation which takes place at about 36°. This is the conversion of the sodium ammonium racemate into the single sodium and ammonium racemates:

$$2(NaNH_4C_4H_4O_6)_2\,2H_2O = (Na_2C_4H_4O_6)_2 + [(NH_4)_2C_4H_4O_6]_2 + 4H_2O.$$

Both the single salts are still racemic, and this change does not concern us at present. But it is interesting to notice that the existence of sodium ammonium racemate in stable equilibrium in contact with water is limited by temperature in two directions. It is only possible between 27° and 36°.

We must now consider the phenomenon of partial racemism (Halbracemie). The name is due to Emil Fischer.* In the course of his marvellous work on the sugars he was naturally brought continually into contact with the phenomena of optical isomerism. From the fundamental stereo-chemical idea it is clear that the presence of four asymmetric carbon atoms in the aldohexoses and the acids derived from them will bring about the existence of sixteen optically active isomerides, grouped in pairs. The members of each pair will possess the antimeric relation, that is, each isomer will combine with one other—its antimere—to a racemic compound. There will be eight racemic compounds. Of course the members of different pairs are remarkably similar in composition, the difference between them being not structural, but geometrical only. The interesting possibility occurred to Fischer that substances not mirror images might combine after the fashion of antimeres to compounds which, while they would be closely

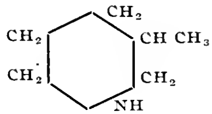
* *Berichte*, xxvii, 3225 (1894).

analogous to the true racemic forms, still might be expected to exhibit differences from them. Two of the pairs above referred to are d- and l-mannonic acid, antimeres, and d- and l-gluconic acid, also antimeres. Fischer attempted to obtain compounds of d-gluconic acid with d- and l-mannonic acid, but without success. He concluded from this that there is no special inclination to the formation of partially racemic compounds, and that the realization of the conception is improbable. We owe the complete certainty that such compounds exist to Ladenburg, who was led in this direction by his synthesis of conine. His work in connection with racemism has been marred by several important blunders, and it is pleasant to be able to credit him in this matter with completely making out his point.

The salts of the two tartaric acids exhibit the phenomena of racemism in the same way as the acids themselves. The replacement of the hydrogen by a metal or by a symmetrical inactive radicle leaves the enantiomorphous relation of the molecules untouched and the behavior associated with this relation persists. But when the hydrogen is replaced by an unsymmetrical active radicle everything is completely altered. The molecules of the two salts are no longer mirror images, the enantiomorphous relation has disappeared and with it the whole mass of correlated phenomena. Thus the salts of the two tartaric acids with the same active base are no longer antimeres and their densities, solubilities, melting points, content of water of crystallization are different, while nothing can be said *a priori* with respect to the crystalline form, except that in all probability the two will crystallize differently.

Now the essence of what is known at present about partial racemism is that compounds like these, not antimeres, can unite, after the manner of enantiomorphs, to form compounds which are called partially racemic (halbracemische Verbindungen). It is easy, reasoning in a similar way, to arrive at the conclusion that the two salts of the two antimeres of an optically active base (for instance, the salts of d- and l-conine) with the same optically active acid

(for example, d-tartaric acid) will exhibit exactly similar behavior. It is possible that the two salts which the base β pipecoline



forms with d-tartaric acid are an instance of this. The base contains an asymmetric carbon atom and accordingly a d- and an l-form are known. It is very possible that the acid d-tartrates of the antimeres unite to a partially racemic compound, but the evidence is not conclusive.* Another instance is the d-tartrate of racemic tetrahydropapaverin.† It is important to notice that partially racemic compounds in general will be optically active, since, from the nature of the case, the activity of either the acid or the base is uncompensated. The optical activity of r-tetrahydropapaverin d-tartrate, for instance, is of the same order as that of the metallic tartrates. Another partially racemic compound is the salt which r.pyrotartaric acid $CH_3CH(CO_2H)CH_2CO_2H$ forms with quinine. Here the acid is responsible for the phenomenon.‡ By far the most completely investigated case is that of the neutral tartrates of strychnine.§ Here the difference between partial and complete racemism is well brought out. We have seen that the properties of antimeres, except the opposed rotation and, when it is present, the enantiomorphous crystallization, are rigorously identical. But the d-tartrate of strychnine contains $6\frac{1}{2}$ and the l-tartrate $3\frac{1}{2}$ of water of crystallization. The melting point of the former is 228°, that of the latter 242°. And the l-tartrate possesses a much higher density and is much less soluble in water than the d-tartrate. When a mixture of equimolecular quantities of the two salts is moistened with about two molecular

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* Ladenburg, *Berichte*, xxvii, 75.

† Pope and Peachey, *Zeitsch. für Krystallographie*, xxxi, 11.

‡ Ladenburg, *Berichte*, xxxi, 524.

§ Ladenburg, *Berichte*, xxxi, 1969.

weights of water the mass becomes dry, owing to the following reaction:

$$d\text{-}C_4H_6O_6.2C_{21}H_{22}N_2O_2 7H_2O + l\text{-}C_4H_6O_6 2C_{21}H_{22}N_2O_2.3\tfrac{1}{2}H_2O + 2\tfrac{1}{2}H_2O = (C_4H_6O_6.2C_{21}H_{22}N_2O_2)_2 13H_2O.$$

It is unfortunate that no crystallographic investigation was made of the isomers and the racemic compound. The results would have been extremely interesting. Of course, there must be here, as in the case of racemic compounds, one place on the thermometric scale where the three solid phases are in equilibrium with solution and vapor. This occurs at 29·5°.* The chief difference between the two cases is that, owing to the unequal solubility of the isomers, the symmetry of the solution curves will disappear and the liquid phase will not, in general, contain equal quantities of the isomers, either at the inversion point or at other temperatures. This point must be insisted upon because Ladenburg found nearly equal quantities of the d- and l-strychnine tartrates in the solution at 30°,† and uses this fact to confirm his contention that, in general, in the case of partially racemic compounds, the solution at the inversion point will contain equal quantities of the two salts. This conclusion is quite erroneous.‡

Leaving the subject of partial racemism we return to true antimeric compounds. The closer the chemical similarity of two substances, the more likely they are to produce solid solutions, or mix-crystals with each other. The fact, therefore, that antimeres do this is not surprising. Our knowledge of this matter has been attained very recently, and is due entirely to the fascinating researches of Kipping and Pope.§ When the antimeres grow together to a solid solution the result is what Kipping and Pope have named the pseudo-racemic mix-crystal. This lies between the mere mechanical mixture and the chemical combination of the two, the racemic compound. All three

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* Ladenburg, *Berichte*, xxxii, 50 (1899).

† Ladenburg, *Berichte*, xxxii, 52.

‡ *Cf.* Bakhuis Roozeboom, *Zeit. f. Physikal. Chem.*, xxviii, 503.

§ *Zeit. f. Krystallographie*, xxx, 443.

are inactive by external compensation and must not be confused with the meso-form, *e. g.*, mesotartaric acid, in which one-half of the molecule reverses the action of the other half. The distinction between the inactive mixture and the pseudo-racemic mix-crystal is simple. The latter is a homogeneous substance—one solid phase, the former a mixture of two. The distinction between the mix-crystal and the racemic compound is a special case of the principle that a compound is a form of matter having its own properties, while the properties of a solid solution* are those of the two constituents, those of each affected, to some extent, by the presence of the other. Thus the crystalline form, density, solubility and so on of a racemic compound will, in general, be quite different from those of the antimeres. But the crystalline form of the pseudo-racemic mix-crystal is so similar to that of the antimeres that crystallographic distinction is difficult, though undoubtedly the angles are slightly different. The faces show multiple reflections and the other characters that crystallographists associate with impure crystals. The density will be close to that of the antimeres, but slight differences will occur. Kipping and Pope consider that the mix-crystal will always melt at the same temperature as the antimeres, and that the inactive mixture will also have the same melting point. Our knowledge of the melting points of isomorphous mixtures is regrettably incomplete,† but it is very unlikely that they are right in this. It is improbable that the statement applies even to the mix-crystal, while, so far as the inactive mixture is concerned, it is certainly incorrect. The only mix-crystal which could well be confused with the racemic compound, that is, the inactive one, containing 50 per cent. of each antimere, melts like a chemical compound at a definite temperature, and does not display the progressive melting of

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* For the purposes of the present paper it is unnecessary to distinguish between mix-crystals and solid solutions in general.

† *Cf.* Küster, *Zeit. für Physikal. Chem.*, viii, 577 (1891).
Centnerszwer, *Zeit. für Physikal. Chem.*, xxix, 715 (1899).
Roozeboom, *Zeit. für Physikal. Chem.*, xxviii, 510 (1899).
Roozeboom, *Zeit. für Physikal. Chem.*, xxx, 385 (1899).

solid solutions. Nothing can be said, *a priori*, about the location of the melting point with reference to that of the antimeres. It may be higher, lower, or at the same temperature.

THE RECOGNITION OF THE PHENOMENON.

The question of the recognition of racemism, of the methods of distinguishing a racemic compound from an inactive mixture or a mix-crystal is of great importance to organic chemistry, and has of late received much attention. Emil Fischer was one of the first to turn his attention to the matter.* He points out that it is only in the solid state that the phenomenon is known with certainty, and remarks that indications as to whether an inactive liquid is racemic or a mere mixture may, perhaps, be obtained from alterations in density, refractive power, magnetic rotatory power, or evolution or absorption of heat when the antimeres are mixed. This was only a tentative statement, and it may be remarked that two of the criteria are of doubtful value, since evolution of heat and alteration of density are common in the mixing of liquids when there is no reason to assume the occurrence of chemical combination. Fischer himself later† called attention to this in connection with the racemism of inactive synthetic conine. Ladenburg had found that when d- and l- conine are mixed in equal quantities there is a slight fall of temperature, and had concluded from this that the liquid is a racemic compound. This, however, proves nothing. Among common liquids, which produce considerable temperature changes when mixed, are alcohol, ether, carbon disulphide and chloroform. Ladenburg‡ has shown that when ether and chloroform are mixed at ordinary temperatures in the right quantities the temperature rises 12°.

In this case there is considerable contraction, while in the mixing of d- and l-conines the density remains unchanged. Ladenburg lays stress on this fact and contends that evolution or absorption of heat without simul-

* *Berichte*, xxvii, 3225.

† *Berichte*, xxviii, 1153.

‡ *Berichte*, xxviii, 1993.

taneous change of density is good evidence of chemical combination, and, therefore, of the racemism of the liquid. It seems to me that the value of this criterion is very slight, for the condition of no alteration in density would almost never be fulfilled, and, when it was, it itself would offer stronger evidence against the combination than a small temperature change would give in its favor. Küster* makes the interesting point that the behavior of the temperature change in time in this case indicates chemical combination. Ordinary temperature changes taking place during the mixture of liquids are instantaneous, while when d- and l-conine are mixed the lowering of temperature requires half an hour to become complete. This indicates a slow reaction going on in the mixed liquid and a correspondingly gradual absorption of heat,

d-conine + l-conine = r-conine.

The literature of liquid racemic compounds is small in amount and inconclusive in character. New methods of attacking the problem are needed.†

With respect to the existence of racemic compounds in solution, the same remarks may be made. From the lack of evolution or absorption of heat when solutions of the antimeres are mixed,‡ and from the conductivity and cryoscopic behavior of solutions of racemic compounds the conclusion has been reached that only the antimeres exist in the liquid, but it is improbable that this is correct. In some cases the solubility relations render it very probable that a considerable proportion of the dissolved substance is racemic.§

It must be remembered that a number of molecular species must be taken into account in discussing the state of things in a liquid in equilibrium with a racemic compound as solid phase. Since most racemic compounds are electrolytes—acids, bases or salts—there may be present the ions of both antimeres as well as undissociated molecules of both and

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* *Berichte*, xxxi, 1847.

† *Cf.* Pope and Peachey, *Proc. Chem. Soc.*, xv, 201 (1899).

‡ Jahn, "Wied. Annalen," xliii, 306 (1891).

§ Küster, *Berichte*, xxxi, 1847 (1898).

polymeric molecules. Then the racemic compound may be present in the same three conditions, and the fact that its molecular weight is unknown must not be lost sight of. If the racemic compound happens to be a salt of a weak acid or base the possibility of hydrolysis further complicates matters. It will be seen that the problem is not an easy one. It becomes simpler in the case of a compound not an electrolyte where electrolytic dissociation and hydrolysis are impossible. Such compounds are not difficult to find—among the sugars, for instance—and the study of their condition in solution would, it seems to me, afford very interesting results. With respect to the possibility of racemism in gases our ignorance is complete. Most racemic compounds cannot be obtained in this condition at all, and the only substances which have been investigated are the esters of racemic acids, *e. g.*, di-methyl racemate. The result of density determinations is always a molecular weight corresponding to that of one antimere, so that it seems that the racemic compound dissociates into the antimeres on being vaporized.

As Fischer has acutely remarked, it is only in the solid state that the characteristic signs of the racemic condition are apparent. We are only concerned with the differentiation of the racemic compound from the other inactive forms, the inactive mixture containing equal quantities of each enantiomorph and the pseudo-racemic mix-crystal of the same composition. The surest way of making the distinction is crystallographic investigation. The conglomerate will often be a mixture of two different crystalline forms bearing enantiomorphous relations to each other. The racemic compound will consist of homogeneous crystals of one species and its form will be absolutely different from that of the antimeres, whether the latter are enantiomorphs or not. The pseudo-racemic mix-crystal will exhibit multiple reflections and the other imperfections which are associated with crystals of impure substances. In form it will possess an extraordinary similarity to the antimeres, but there will be small differences in the angles. Its inactivity at once distinguishes it from the enantiomorphs and its crystalline form

from the racemic compound. Unfortunately the method requires good crystals and is not always applicable.

Fischer has pointed out that at times the distinction can be made by chemical analysis, for example, when the antimeres are salts containing water and the inactive substance contains either more or less water. Such cases have long been known among the tartrates. Inactive calcium mannonate is anhydrous, while the antimeres contain water of crystallization. Kipping and Pope* consider that all mixtures of the antimeres and all solid solutions of them will melt at the same temperature as the antimeres separately. Hence, when the inactive substance has a different melting point it is to be regarded as a racemic compound. This conclusion is certainly erroneous. Fischer's cautious statement that when the inactive substance has a higher melting point than the antimeres it is certainly racemic, while, if lower, no decision can be made,† has won the general assent of chemists, but even this generalization must be qualified. The possession of a higher melting point than that of the antimeres does, indeed, distinguish the racemic compound from the inactive mixture, but not from the pseudoracemic mix-crystal, since this may melt either higher or lower than the antimeres separately. The inactive mixture of equal quantities of the antimeres has the lowest melting point of all conglomerates of the two, while the pseudo-racemic mix-crystal has either the lowest melting point of all solid solutions, or else the highest, unless the melting point is the same for all concentrations. Finally, the racemic compound is simply a pure substance with its own melting point. The effect of mixing a little of either antimere to the racemic compound will be to lower the melting point just as any other foreign substance would do. But the effect on the inactive conglomerate will be to raise the melting point. With the pseudo-racemic mix-crystal the same addition may raise the melting point or lower it, or leave it unchanged.

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* *Zeitschrift für Krystallographie*, xxx, 443; also *Jour. Chem. Soc.*, lxxi, 989.

† *Berichte*, xxvii, 3225.

It is clear that we can easily distinguish the compound from the conglomerate by means of melting point determinations, but not from the mix-crystal. This same distinction can be very readily made by a solubility determination. Consider a solvent in equilibrium with both enantiomorphs as solid phases. Since both dissolve in equal quantity at all temperatures the liquid will be inactive. Now, let either solid antimere be added to it. The solution being already saturated with respect to this substance, the sole effect is to increase the amount of that particular solid phase; the liquid remains inactive. But with the liquid in equilibrium with the solid racemic compound everything is different. None of the antimeres being present as solid phase, the solution is unsaturated with respect to it, and it dissolves at once, the liquid of course becoming active. It follows from the fundamental principles of the phase rule that the liquid in equilibrium with a pseudo-racemic mix-crystal will become active on adding either antimere. So, also, when the inactive substance is a liquid the solution over it will be made active by adding either antimere, whether the liquid is racemic or not. The criterion is, therefore, completely inapplicable to liquids, and Ladenburg's recent attempt to prove the racemic character of inactive conine and limonene by means of it is a surprising blunder.

I have given here only those facts with respect to melting point and solubility which are most likely to be of value to the organic chemist. The exhaustive discussion of the solubility and fusion relations of mixtures and compounds of enantiomorphous isomers is inseparably bound up with the general doctrine of the phase rule, and to attempt anything like a detailed treatment of the subject within the limits of the present paper is impossible.*

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* Bakhuis Roozeboom has recently published two papers on this subject. The shorter one (*Berichte*, xxxii, 537) is an abridgment of the other, and, like all abridgments, very unsatisfactory reading, but the complete paper (*Zeit. Physikal. Chem.*, xxviii, 494) will become a classic in chemical literature. It is remarkable for exactness and for lucidity of statement.

THE SEPARATION OF THE ANTIMERES.

Owing to the identical solubilities of the antimeres and to the sameness of their chemical behavior toward symmetrical substances, their separation by ordinary methods is impossible. For the same reason when a carbon atom becomes asymmetric the product is the inactive mixture or the racemic compound, the two isomers being produced in equal quantities. This impossibility of producing one enantiomorph without the other from inactive substances and under symmetrical non-selective working conditions was a favorite thesis of Pasteur, and a recent revival of the idea in a somewhat different form* has given rise to much controversy. The difference between the two views is that Pasteur's was simply a tentative working hypothesis which he was ready to abandon at any time, while Japp regards the production of a single antimere under the conditions stated as inconceivable and the impossibility of doing so as a permanent limit to the achievements of our science.

The conclusion is that the optically active substances which exist in nature must have been produced by the action of some unsymmetrical force which appeared upon the scene at the same time as life, and which, presumably, is identical with the vital force of the older biologists. Pasteur's statement was valuable in his hands because it often led to predictions which were verified by experiment, but it is clear that Japp's extension of it does not fulfil the requirements of a scientific hypothesis.

Most of Japp's critics were not chemists, and were hampered by lack of acquaintance with the subject under discussion, but two of them, whom we can hardly accuse of unfamiliarity with chemical matters, have shown that it is perfectly possible to imagine symmetrical conditions under which one enantiomorph would be produced to the exclusion of the other.† ‡

Pasteur worked out three methods of separating the

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* Japp, *Nature*, lviii, 452, and many following numbers.

† Ostwald, *Zeit. Physikal. Chem.*, xxix, 347 (*Ref.*)

‡ P. Frankland, *Nature*, lix, 30.

antimeres. The first is applicable only to a mixture of well-developed enantiomorphous crystals, and consists in the simple picking out of the two kinds. Thus when the solution of sodium ammonium racemate crystallizes, right and left enantiomorphous forms are deposited side by side. Each can be made to yield its own kind of acid, and so the preparation of a whole series of antimeres becomes possible. The method has not been found generally applicable, because it is difficult or impossible in most cases to obtain crystals distinct enough for the selection to be made.

The second method applies only when the enantiomorphous substances to be separated are bases or acids, a very frequent case.

If they are acids the mixture is treated with an active base; if bases, with an active acid. In either case two salts will be produced in the solution and one of them will crystallize first, and by recrystallization can be obtained pure. Thus Pasteur separated d- and l-tartaric acids by adding cinchonine when the cinchonine l-tartrate crystallized out. He considered that l-tartaric acid had a stronger affinity for the base than the dextro-acid, and hence its salt was formed, the latter remaining free. This view is still general, but since it is in complete discord with the doctrine of affinity and with the results of experiment it must be abandoned.

Antimeric acids, being equally dissociated at all dilutions, must exhibit the same affinity toward all bases, asymmetric or not, and the same thing is true of antimeric bases. This statement has been abundantly confirmed by direct experiment.* † Thus the heats of neutralization of the two tartaric acids with the active bases, morphine and nicotine, are the same. The dextro- and lævo-tartrate of cinchonine raise the boiling point of water to an equal extent, demonstrating that the electrolytic dissociation and hydrolysis of the salts at equivalent dilutions are identical. This could

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* Jahn, "Wiedemann's Annalen," xliii, 306 (1891).

† Marckwald and Chwolles, *Berichte*, xxxi, 783 (1898).

not be the case if the affinities of the two acids for the base were different. Finally, when inactive methyl-ethyl-acetic acid or inactive mandelic acid is one-half neutralized with brucine in aqueous solution the rest of the acid, extracted by ether from the liquid, is inactive. Clearly, if the brucine had combined preferably with either acid the other one would have predominated in the ether extract.

The fact is that the crystallization of one salt in such separations is purely an affair of solubility. Both salts are produced in equal quantities, but they are no longer antimeres and differ in all respects, solubility included. That one crystallizes first which is least soluble under the conditions of the experiment. This method of separation has been largely employed by Ladenburg and others. For the separation of asymmetric bases, d-tartaric acid is often used; for that of enantiomorphous acids, quinine, cinchonine and strychnine are in favor. Pasteur's third method was the biological one. The solution of the inactive substance is sown with the spores of a mould, penicillium is frequently used, and nutrient material is added. One isomer is destroyed, the other remains. The method has been successfully employed, though the destruction of one isomer is a disadvantage, especially as the choice rests with the mould and not with the investigator. Sometimes the substance acts as a poison for the micro-organism; it does not grow, and the product is unchanged in quantity and still inactive. This happened, for instance, when Ladenburg attempted to separate synthetic conine by this method. Recently two new methods of separation have been added to these classical ones. Kipping and Pope have found that the solubilities of the antimeres are no longer identical when the solution contains a third asymmetric substance. This substance must have no chemical action upon the antimeres or the dissolving liquid. Thus, when inactive d- l-sodium ammonium tartrate was crystallized from water containing dextrose, the first crop of crystals contained a considerable excess of dextro-tartrate. I consider it probable that the solubility of the antimeres will be found to be different where the solvent itself is active. Suitable solvents could

be found, for instance, among the active alcohols. Further, it should not be difficult to find a case where the solvent crystallizes with the antimeres as alcohol of crystallization. The question whether each would separate with the same number of molecules of the solvent as they always do with water and symmetrical solvents in general is of great interest.

The second of the new methods rests upon the fact that the speeds with which the antimeres react with an asymmetric substance are different.* If, then, the process is interrupted before the reaction is complete, the unchanged substance will contain an excess of one antimere and the reaction product of another, and from either, by suitable methods, the isomer which predominates can be isolated. For instance, when lævo-menthol is heated with inactive mandelic acid the dextro-acid is estrified most rapidly, and if the reaction is interrupted after it has continued for an hour, lævo-mandelic acid can be isolated unchanged from the product. Further, the esters of the two mandelic acids with lævo-menthol, and in general the esters of antimeric acids with an asymmetric alcohol, are no longer enantiomorphs and exhibit chemical differences on which a separation can be based. When an equimolecular mixture of lævo-menthyl lævo-mandelate and lævo-menthyl dextro-mandelate is saponified, the dextro-ester is attacked more rapidly, and if the saponification is carried out in two fractions the acid from the first is dextro-rotatory, that from the second lævo-rotatory. Of course, both acids are mixtures, but from both that isomer which is present in excess can be isolated. The method of Marckwald and McKenzie is new, and owing to the extraordinary rapidity with which work accumulates in this field, the authors have felt constrained to publish it with only a few preliminary experiments. Many difficulties are to be overcome before the procedure can rank as a useful method of separating enantiomorphs. The authors have promised to proceed imme-

* Marckwald and McKenzie, *Berichte*, xxxii, 2130 (1899).

diately with the experimental investigation, and chemists will await their results with much interest.

CENTRAL MANUAL TRAINING SCHOOL,
DEPARTMENT OF CHEMISTRY,
PHILADELPHIA, January 16, 1900.

ADDENDUM.—In the first part of this paper attention is called to the fact that the phenomena of racemism are dependent upon the presence in the molecule of a carbon atom united with four different radicles, or of a nitrogen atom united with five different groups, an asymmetric carbon or an asymmetric nitrogen atom. Since this was written Pope and Peachey,* in a most interesting preliminary communication, have announced the preparation of racemic derivatives of tetravalent tin, and the asymmetric tin atom has been added to our science.

The authors started from the tin trimethyl iodide of Ladenburg and Cahours. From this they obtained methyl-ethyl-n-propyl tin iodide by methods which are indicated in the following equations:

$$2Sn(CH_3)_3I + Zn(C_2H_5)_2 = 2Sn(CH_3)_3C_2H_5 + ZnI_2,$$
$$Sn(CH_3)_3C_2H_5 + I_2 = Sn(CH_3)_2C_2H_5I + CH_3I,$$
$$2Sn(CH_3)_2(C_2H_5)I + Zn(C_3H_7)_2 = 2Sn(CH_3)_2(C_2H_5)C_3H_7 + ZnI_2,$$
$$Sn(CH_3)_2(C_2H_5)(C_3H_7) + I_2 = Sn(CH_3)(C_2H_5)(C_3H_7)I + CH_3I.$$

This methyl-ethyl-n-propyl tin iodide contains an asymmetric tin atom. It is a yellow oil, almost insoluble in water. Its vapor attacks the mucous membranes. Like all the products of synthesis, it is inactive by external compensation, equal quantities of the d- and l-isomers being produced.

In order to obtain an active product the substance was treated with the silver salt of d-camphor-sulphonic acid in aqueous solution, when d-methyl-ethyl-n-propyl tin iodide d-camphor sulphonate,

$$Sn(CH_3)(C_2H_5)(C_3H_7)(C_{10}H_{15}OSO_3),$$

separates. This is strongly dextro-rotatory. The corresponding lævo-salt could not be obtained. When the

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**Proceed. Chem. Soc.*, xvi, 42 (1900).

mother liquor was evaporated nothing but fresh quantities of the dextro-salt were obtained, an extremely interesting phenomenon and one readily explained by rapid auto-racemization restoring the equilibrium continually disturbed by the separation of the less soluble dextro-salt. Finally, when the solution of this salt is treated with aqueous KI, d-methyl-ethyl-n-propyl tin iodide separates as a yellow oil which was decidedly dextro-rotatory. The mobility of the radicles attached to quadrivalent tin appears to be surprisingly great, and at times the oil is inactive, in consequence of auto-racemization. Walden has shown that the same thing takes place with asymmetric carbon compounds, but very much more slowly.

The authors are of the opinion that all compounds with enantiomorphous molecular configuration, at least all those in which the asymmetric atom belongs to Mendelejeff's fourth or fifth group, will be found to exhibit optical activity. They are engaged in the attempt to prepare active derivatives of tetravalent lead.

PHOTOGRAPHIC AND MICROSCOPIC BRANCH.

Stated meeting held Tuesday, December 5, 1899.

IMPROVED METHOD FOR MOUNTING PRINTS.

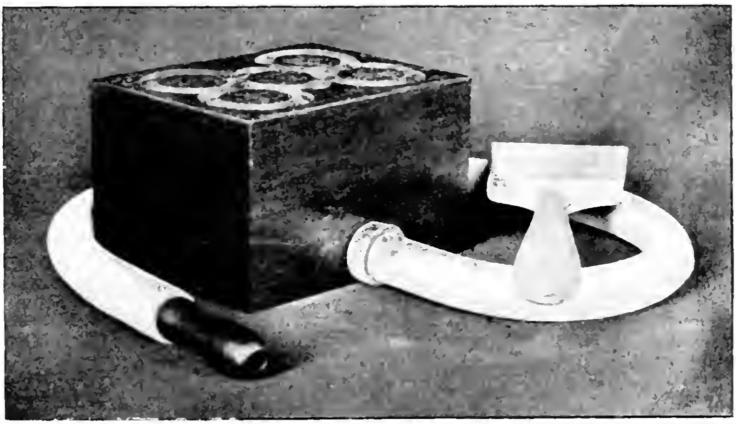
By John G. Baker,
Member of the Section.

Often, the troublesome part to the amateur photographer is the mounting of the print. The cause of this is that, by the old method, it requires some practice, which he has not had; for the number of prints he has to mount is so small that he prefers to get them in shape for the album, especially after he has tried his hand at mounting the first few prints in the old way and making a mess of it.

Now, to remedy this trouble I have contrived the device I have here this evening and of which I will give you a brief description and a practical demonstration.

This invention is for the mounting of squeezed or other dry prints. The method has several advantages. It is very simple, neat and clean; stops all daubing of the prints and leaves them and the hands quite clean. The mounts have less tendency to curl, and as the prints are quite stiff, they are more readily handled, and if they are to be colored, it may be done before they are mounted, and there is, therefore, less danger of soiling the mount. To the inexperienced person this method is well adapted, since it requires but very little skill to make quite a neat job of it.

The arrangement consists first of a block of wood, which is called the squeezed print mounter. This block is made



about $\frac{1}{8}$ inch smaller than the print to be mounted, and its upper surface is formed with a series of circular grooves, each of which is in communication with its neighbor, and the whole system in communication with the outlet pipe near the bottom of the mounter. To this outlet is attached a piece of rubber hose, and to facilitate the handling of the prints a small paddle is also added. To keep the prints more firmly in place, the upper surface of the mounter is coated with a solution of rubber cement, made quite thin with benzine. This coating must be renewed whenever the surface gets too smooth to hold the prints firmly.

To use this mounter, place the print upon it face down,

with the edges projecting all around, and on it, to hold it in position temporarily, place the paddle, then prepare the brush with as much paste as needed, after which place the rubber hose in the mouth and exhaust the air; this holds the print whilst applying the paste; after the print is pasted, apply the paddle to it, so that it may be readily transferred to the mount, place one edge in its proper position on the mount, and with the left hand hold it there, until you remove the paddle, after which proceed as in the older method.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1899–1900.

This has been a very successful year with the drawing school, not only as to the number of students, but also as to their character. The general prosperity of the industries of the city has had much to do with this result, but, in addition, the fact is slowly becoming known that a definite, progressive, logical and comprehensive course of instruction is pursued here, which gives a maximum of efficiency with a minimum of time and labor. There is given in our school just such a blending of the science and practice of the art as to make the study interesting and effective, and at the same time desirable, to students whose previous knowledge and experience are very different. The college student, proficient in geometry, can see how the problems that bored him so in the abstract are usefully applied, the apprentice in the draughting room can learn the principles underlying the work that he is doing in detailing and tracing the drawings of his seniors, and the foreman or mechanic can acquire the skill and technique to enable him to make his own drawings and to readily and accurately read and understand those to which he is obliged to work. The requirements necessary to obtain and maintain a position are constantly increasing, and in the mechanic arts a considerable knowledge of draughting has become a necessity. This school effectually supplies that knowledge.

WM. H. THORNE, *Director.*

THE FOLLOWING STUDENTS ARE ENTITLED TO HONORABLE MENTION:

In the Senior Mechanical Class.

John Oldman, George F. Eisenhardt,
Samuel Greenlee, Emil Paul Hottinger,
Fritz H. Larsen.

In the Intermediate Mechanical Classes.

Clarence Fithian, Walter Topliff,
C. B. F. Waller, J. Benjamin De Hart,
Edward Flegel, Lionel F. Levy,
John Hoffman, C. E. Moldrup,
John Vallely.

In the Junior Mechanical Class.

Richard Poeckert, Thomas F. Jones,
Joseph Roberts, Eugene Fischer,
John Zerbe, Robert McAlees, Jr.

In the Architectural Class.

Roy E. Blithe, J. Henry Slaugh,
Harry C. Beatty, Daniel Sharp,
J. De Frehn.

In the Free Hand Class.

Robert F. Plum, James J. Dunn,
Clarence Bellet.

THE FOLLOWING STUDENTS ARE AWARDED SCHOLARSHIPS FROM THE B. H. BARTOL FUND, ENTITLING THEM TO TICKETS FOR THE NEXT TERM:

Frederick Schwartz, Theodore R. Johnson,
Frederick Woodward, James R. Calhoun,
A. D. Thomas, Alfred Whitney.

THE FOLLOWING STUDENTS, HAVING ATTENDED A FULL COURSE OF FOUR TERMS WITH SATISFACTORY RESULTS, ARE AWARDED CERTIFICATES:

William Welch, Samuel Greenlee,
John A. Proud, George F. Eisenhardt,
Herman A. Langefeld, Robert Koeberle,
Joseph F. Klinger, Arthur Schwab,
John Oldman, Frederick Rieman,
Fritz H. Larsen, William H. Hollar, Jr.,
John W. Manogue, Roy E. Blithe,
George Cummings, William H. Gould,
William Williams, Robert F. Plum.

Branch School.

Johan Olof Hofman.

CORRESPONDENCE.

FALLACIES OF TEXT-BOOKS.

To the Editor of the Franklin Institute Journal:

It was in the columns of this *Journal*, if my memory serves me correctly, that the attention of the engineering fraternity was called to the error in many of the text-books relative to the loss of head by a current of water in a pipe, when the current underwent a deflection, many of the text-books showing the angle to be that made by the intersection of the two lines of pipe instead of the angle of deflection.

It was also in the columns of this *Journal* that the attention of engineers was

called at an early date to the fact that the exhaust edges of a slide valve had considerably to do with the economy of a steam engine and that "lead" was detrimental unless accompanied by suitable compression.

More recently the fallacy of the so-called "law of partial pressures" has been criticised and exploded, and a more rational base of the volumes substituted.

I desire now to call the attention of those who are interested to other fallacies, which, the sooner they are exploded and obliterated, the sooner a solid foundation will be secured, and new methods and means formulated by which and upon which engineering calculations may be more safely based for future work.

It is only necessary to refer to almost any text-book, technical, periodical or trade journal to find elaborate calculations based largely, if not entirely, upon the specific heats of various fluids (and especially of the gaseous ones), in which the specific heats, regardless of temperature or pressure, are treated as constants. The experiments and investigations of such careful scientists as Wroblewski, Olszewski, Witkowski, Amagat, Mollier and Lussana have thoroughly exploded this fallacy and have clearly demonstrated that the specific heats of many, if not all, of the gaseous fluids increase with both the temperature and pressure in many cases several hundred per cent. Moreover, it is at least suggestive, if not probable, that in most cases these increments of specific heats are additive when both temperature and pressure are changed from normal conditions.

Again, more recent investigations by scientists have thrown such serious doubts upon what has heretofore been known as "absolute zero" as to make this quantity in practical calculations not only absolutely useless, but exceedingly misleading; so much so, that I sincerely question whether any scientists at the present day, who are familiar with the present aspect of the subject, would feel warranted in stating positively that there is such a point as "absolute zero," and if there is such a point, whether or not it is within several hundred degrees of its present assumed position on the thermometric scale. These are all questions of the most serious importance, not only to the scientist, but particularly to the practical constructing engineer, who may be engaged in the construction of new machinery, involving the compression and liquefaction, expanding and vaporizing of gases for various purposes, such as refrigeration and the production and distribution of power by compressed air or other gases. And while I am not particularly anxious to raise the questions relative to the second law of thermodynamics so ably discussed in the columns of this *Journal* many years ago by Professors Klein, Thurston and others, the engineer cannot ignore the facts brought out by more recent investigators and the bearing that these facts have upon this matter. Moreover, it seems almost like a "thermodynamic heresy" to suggest anything that would invalidate the practical utility of the beautiful entropy or theta-phi diagrams, so ably treated by Professors Boulvin, Reeve, Golding, Richmond and others. However, facts are no respecters of either persons or things, and if it *is* true that the specific heats of gases change materially by variation from the normal, of either temperature or pressure, or both, and if it *is* a fact either that there is no such a condition as that heretofore conceived as "absolute zero," all of the beautiful formulas so elaborately set forth in the text-books

relative to adiabatic compression and expansion, and in fact all other formulas or calculations of any kind based upon the alleged "absolute zero," must either be entirely elimiuated or so modified as to meet the new conditions, in place of being based upon the former erroneous assumptions.

Without wishing to influence the opinions or actions of others in the premises, my own conclusions based upon recent researches and investigations are that the larger part, if not all, of the thermodynamic formulas, as appear in the text-books, are not only untrue, but absolutely misleading; that the point on the thermometric scale known as absolute zero either has no existence in point of fact (which is the most probable), or if there is such a point, it is so far below its preconceived position that it cannot be used in engineering calculations to any extent whatsoever for practical purposes; that the change in the specific heats of gases, by variation in temperatures and pressures, are so great that these values are also not only useless, but misleading, to the engineering profession, when they are made use of in calculations upon which to construct machinery for practical purposes; that there is not a sharp line of demarkation between the liquid and gaseous condition of the matter, but that the lower the temperature, the sharper the line, the higher the temperature, the less distinct becomes the line of demarkation until the critical point is reached; that, with fluids, the critical temperature of which is above that of the normal temperature, the specific heat of the fluid in gaseous state increases both with an increase of temperature and pressure until the critical state is reached, at which point the specific heat then becomes that due to the fluid, at that point, and that the change in specific heat from one state to the other is gradual.

I am aware that these ideas may be, and probably will be, called "thermodynamic heresies," and that in ancient times people have been put to death for the expression of less radical ideas than these; however, I annunciate them for what they are worth, and expect that if the same are not ignored by those who are better able to discuss them than I am, to be severely criticised. I am simply seeking the facts, and will certainly have no unpleasant feelings toward any one who differs with me in the premises, and only the most pleasant feelings toward those who may feel disposed to show me that I am in the wrong. E. F. OSBORNE.

CHICAGO, ILL., April, 1900.

NOTES AND COMMENTS.

THE PASSING OF THE LINK AND PIN.

A branch of industry which will, ere long, become extinct, is the manufacture of links and pins for coupling railroad cars. Automatic coupling devices render unnecessary the use of these ancient contrivances for fastening cars together. The adoption of automatic couplers has been hastened by national legislation, even though the time has been considerably extended before the penalties are imposed, and years have passed since the Congressional enactment first went into effect without the punishment of any railroad official for tardiness in making the improvement. So much progress has been shown

in changing the equipment of cars that the day is undoubtedly near at hand when links and pins will only be seen in collections of railroad curios. Railroad supply houses which once handled them in carload lots, and kept large stocks to meet the steady demand, now find their orders calling for a few at a time, while such orders are likely to be far apart. The passing of the link and pin is simply another illustration of the march of progress. Apart from the danger to railroad operatives, the old-fashioned method of coupling cars is objectionable as applied to modern rolling stock, and would probably have been supplanted in due course by the automatic coupler, even without a compulsory law.—*Iron Age.*

DISSOCIATION OF AIR AT ORDINARY PRESSURE.

Prof. Raoul Pictet, of Geneva, Switzerland, whose name is identified with the early liquefaction of air and gases, recently made a demonstration, says the *New York Sun*, of a process of his invention for the separation of the oxygen and nitrogen of the air at ordinary pressure.

It is said that the process is one that is about to be introduced in this city on a commercial scale. Professor Pictet's process as described consists in the initial production of a certain quantity of liquid air which is stored in tubes. Then through this is forced, under a pressure of only about one atmosphere or 15 pounds to the inch, a stream of atmospheric air. This is cooled in the liquid air, but as it rises in a chamber beyond the gases of which it is composed separate themselves by gravity and run off in separate tubes. The oxygen, being slightly the heavier, flows out through the lower tube, while the nitrogen goes off above. In addition to these gases, the air contains as an impurity carbonic acid gas, and this, it is asserted, leaves the machine in a liquid form, being reduced to that form by the low temperature. In ordinary liquid air as it is produced by Tripler, Ostergren and others, the carbonic acid gas is frozen and gives the liquid air a milky appearance. It is taken out by pouring the liquid air through an ordinary paper filter.

In a demonstration recently the apparatus used was of the laboratory character, and the proof of the effect was made by exposing a burning bunch of tow to the end of the pipe whence oxygen was expected to flow, where the combustion was made more intense, while at the end of the other pipe the neutral nitrogen diminished or extinguished the flame.

In the commercial machine it is promised that with an expenditure of 500 horse-power the daily output will be 500,000 cubic feet of oxygen, ranging from 50 to 90 per cent. in purity, and 1,000,000 cubic feet or more of nitrogen of similar quality. In addition, it is promised that 1,500 pounds of liquid carbonic acid will be produced.

The two products for which a direct commercial use is expected to be found are the oxygen and the liquid carbonic acid gas. The latter already has a fixed place in the market and large quantities of it are saved in well-equipped breweries, where it is produced in great bulk through the fermenting of beer. It is pumped into steel tubes under a pressure that liquefies it. It is worth about 7½ cents a pound.

The great market which Professor Pictet expects to find for the oxygen is to support combustion at high temperatures in furnaces where coal is burned,

making such fires available for purposes which only the electric arc is now suitable for, as well as making a great economy in producing heat for ordinary purposes. In burning fuel with the oxygen of the air there must be admitted to the furnace about three times the bulk of oxygen or nitrogen, and this absorbs a large quantity of the heat. If an excess of air goes into the furnace, this also takes up and wastes heat. By admitting oxygen these losses can be saved. This saving, Professor Pictet thinks, would equal 40 per cent. of the present fuel bill.

It is proposed to put the oxygen in tubes or tank cars and ship it to consumers. Of the theoretical value of it there can be no doubt. The commercial feature remains to be demonstrated. The nitrogen, it is asserted, can be used for the production of nitric acid, and Professor Pictet says that by a process of his invention he can combine it into ammonia directly by exposing hydrogen and nitrogen to the electric arc under certain conditions. If this be true, Professor Pictet has solved a problem of wonderful value which has defied the researches of the ablest chemists of the world.

Concerning the foregoing statements there would appear to be reasonable probability that Professor Pictet has succeeded in practically solving the important problem of separating the constituents of the atmosphere, which in itself is an important accomplishment. The fixation of the atmospheric nitrogen in the form of ammonia, the heat of the electric arc, has repeatedly been attempted and without success. W.

BOOK NOTICES.

La Telegraphie sans Fils. Par André Broca, Professeur de Physique à la Facultéde Medecine. Paris: Gauthier-Villars. 1899. 16mo, pp. 262, with 34 figures in the text. (Price, 3.50 francs.)

This work is intended to serve the convenience of those who, although not specialists, are interested in the most recent advances of science, and who desire to keep themselves *au courant* with its applications. W.

Les Recettes du Distillateur. Par Ed. Fierz. 16mo, pp. 149. Paris: Gauthier-Villars. 1899. (Price, 2.75 francs.)

This volume contains 140 receipts for the preparation of divers liqueurs, crêmes, etc., concluding with instructions respecting the composition of various coloring matters indispensable to the distiller. W.

Small Engines and Boilers. A manual of concise and specific directions for the construction of small steam engines and boilers of modern types, from 5 horse-power down to model sizes. By Egbert P. Watson. Illustrated by thirty full-page working dimensional drawings. New York: D. Van Nostrand & Co. 1899. (Price, $1.25.)

This work has been prepared for the special benefit of amateur and other non-professional workers who need a guide for the construction of small engines and boilers, and who are presumed to have some acquaintance with

ordinary machine work, and some facilities for doing such work. The author has made his instructions very clear, and, with the aid of his dimensioned plans, the book should prove very useful to the class for which it has been prepared. W.

Photographic Mosaics. An annual record of photographic progress. Edited by Edward L. Wilson, Editor of "Wilson's Photographic Magazine," etc. Thirty-sixth year. 12mo. New York: Edward L. Wilson. London: Dawborn & Ward, Ltd. 1900.

The edition of this well-known photographic annual has retained in its thirty-sixth volume the general features with which its army of readers are familiar.

It embraces a résumé of photographic progress in 1899, covering every branch of the art; and a section of original contributions from well-known experts; the whole covering 288 pages, and embellished with a number of pictures from the best professional workers. W.

Compend of Mechanical Refrigeration; a comprehensive digest of applied energetics and thermodynamics for the practical use of ice manufacturers, cold storage men, contractors, engineers, brewers, packers and others interested in the application of refrigeration. Third edition. By J. E. Siebel, Director Zymotechnic Institute, Chicago. Chicago: H. S. Rich & Co., 1899. 12mo, pp. 389. (Price, in cloth, $3.00; in flexible morocco, $3.50.)

The author appears to have condensed in this small volume a large amount of information, theoretical and practical, bearing upon the subject of refrigeration and its numerous practical applications in the arts. It should prove of special utility to engineers and others who are directly interested in the use of refrigerating machinery, since the author, in addition to devoting special chapters to the practical application of refrigeration, has collected and presented in convenient form a large body of rules, tables and formulæ which will be found of much value for readily answering many questions that arise in the practice of the art. W.

Victor von Richter's Organic Chemistry; or chemistry of the carbon compounds. Edited by Prof. R. Anschütz (assisted by Dr. G. Schroeter). Authorized translation by Edgar F. Smith, Professor of Chemistry, University of Pennsylvania. Third American from the eighth German edition. Volume II. Carbocyclic and Heterocyclic Series. Philadelphia: P. Blakiston's Son & Co. 1900. (Price, $3.00.)

The present edition of this admirable work needs no special endorsement to commend it to students and teachers. It embodies the latest theoretical and experimental developments of this branch of the science of chemistry. The translator's share in the work has been thoroughly well done, and the publishers have issued it in their customary creditable manner. W.

Some Properties of Rocks and Soils in Relation to the Search for Potable Water and the Perforation of Tunnels. By Prof. Gustavo Uzielli.

The conclusions reached in this pamphlet, especially those regarding the expansion of soils due to air chambers formed by the filtration of water and

the contraction which these chambers produce upon tunnels in process of construction, are of considerable importance in the application of geology to engineering. The experiments performed by the author to show the formation of air chambers by water filtration through various kinds of soil are very interesting and convincing. The work throughout is an exhibition of profound thought and clearness, and should be brought to the notice of every engineer interested in geological studies. L. D'A.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 18, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1900.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 96 members and visitors.

Additions to membership since last month, 29.

The Actuary's report contained the following reference: "The Board * * announces, with extreme regret, the decease of the Senior Vice-President of the Institute, Mr. Chas. Bullock, who died March 21, 1900." The President stated, in connection therewith, that the Board, in special session, had adopted formal resolutions of respect to the memory of its deceased member and officer, and that a committee had been appointed to prepare a suitable memorial for publication in the *Journal.*

A special election was held to fill the vacancy in the vice-presidency caused by the death of Mr. Bullock, and resulted in the election of Mr. Washington Jones.

The vacancy in the Board caused by the election of Mr. Jones to the vice-presidency was filled by the election of Mr. Samuel F. Houston.

Dr. Joseph W. Richards, of Lehigh University, Bethlehem, Pa., presented an interesting communication on "Recent Progress in the Aluminum Industries."

Dr. Richards referred more particularly to the steadily increasing use of the metal for the production of a great variety of decorative articles; for electrical conductors in place of copper; for culinary vessels; for lithographic work; and, in the form of powder, as a flash-light in photography; as a paint for protecting exterior iron work, and for the reduction of the oxides of the difficultly reducible metallic oxides, such as chromium, manganese, titanium, vanadium, etc. The speaker illustrated his remarks by the exhibition of a large collection of specimens, and performed the interesting experiment of reducing chromic oxide with powdered aluminum.

Mr. S. Ashton Hand made some most instructive remarks on the "Development of Negatives," giving the results of his long experience in the art of correcting defects in negatives due to over-exposure, under-exposure and other defects familiar to photographers. Mr. Hand illustrated his remarks by the

exhibition of a series of negative and positive lantern slides of the same subject, in which these various defects and their proper treatment were shown in a most instructive way.

Mr. Chas. P. Jacobs described and exhibited an improved apparatus for aërating beverages, which involved the employment of small steel capsules filled with liquid carbonic acid.

The Secretary made some comments on the recently devised process of Mr. E. G. Acheson for converting anthracite culm into graphite, and exhibited a number of samples of the product, which, according to analyses, was almost chemically pure. The process of Mr. Acheson's method is a development of his electric furnace process for producing carborundum.

Messrs. Wm. R. Webster and Carl Herring were appointed delegates of the Institute to the various Scientific and Technical Congresses to be held in connection with the Paris Exposition.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, April 4, 1900.*]

MR. H. R. HEYL in the chair.

The following reports were adopted :

Rail Joint.—Harry Villenoweth, Philadelphia.

ABSTRACT.—The invention is the subject of letters-patent of the United States, No. 574,466, dated January 5, 1897, granted to applicant, and is designed to effectively hold the contiguous rails in alignment and prevent their longitudinal displacement ; also, to take the place of the ordinary fish-plates by substituting a brace on each side of the rail, extending beneath the rail. After examination, the sub-committee charged with the investigation reported that the device contained too many parts for any joint to work properly at the connecting ends of rails where expansion and contraction must be provided for and vertical stiffness obtained; also, that there are numerous other joints in use which come nearer to meeting the requirements of railway service than the invention under consideration. Certain specific mechanical objections are also referred to in detail. [*Sub-Committee*, J. J. DeKinder, Chairman; Jos. T. Richards.]

Round-lap Baling System for Cotton.—American Cotton Co., New York.

ABSTRACT.—By the system and machinery employed by the American Cotton Company a product is made which is known commercially as "Round-lap Bale Cotton," which is said to have advantages possessed by no other bale in the market. For example, each and every bale can be unrolled clear to the center, and, as they are unwrapped, can be fed to the lappers without extra hand labor, and several bales can be unrolled and fed into the lapper at the same time, thus mixing automatically. After specifically pointing out these advantages, the report concludes as follows:

"From a great mass of evidence which the Sub-Committee has gathered, it appears that the Round-lap Bale System introduced by the American Cotton Company has positively done away with all the objectionable features of the old-style 'square-bale' method of baling cotton, against which the cotton spinners of Europe and America have been protesting for many years; and, incidentally, that the new system has introduced large economies, the benefits of which are enjoyed by producers and factors as well as by the spinners."

The award of the Elliott Cresson Medal is made to the American Cotton Company in recognition of the importance of the revolution in the cotton industry brought about by the introduction of the "Round-lap Bale System."

Also, the award of the John Scott Legacy Premium and Medal is recommended to Magnus Swenson, for his invention of the Round-lap Baling Cotton Compress. [*Sub-Committee*, Chas. E. Ronaldson, Chairman; James Christie, M. R. Mucklé, Jr., Chas. A. Teal.]

Press for Compressing Cotton, etc.—Geo. A. Lowry, Chicago, Ill.

ABSTRACT.—This machine is equally well adapted to compress and bale cotton and all varieties of fibrous materials, coarse and fine hay and metal scrap.

In the case of cotton, the machine obviates the necessity of two distinct compressions, to which square-bale cotton is usually subjected. The machine may be erected and operated at the cotton-gin, where the cotton as it leaves the gin falls or is fed into the hopper of this compress, where it is subjected to one compression, baled, wired, put into bags and shipped to its destination and without further manipulation.

After describing in detail the mechanical features of the Lowry press (which would not be intelligible without the aid of illustrations), the report proceeds to enumerate the meritorious features of the machine as follows: These consist in (1) its adaptability to bale and handle a great variety of materials; (2) its general efficiency; (3) the uniformity and density of the finished product, and certain specific mechanical advantages which are enumerated. Together these constitute new and important features in apparatus of this class. The report dwells also on the fact that the machine is applicable to the compression of a large class of raw products.

The importance of the invention is recognized by the recommendation of the award of the Scott Legacy Premium and Medal. [*Sub-Committee*, Chas. E. Ronaldson, Chairman; M. R. Mucklé, Jr., James Christie and Chas. A. Teal.]

Improvements in Steam Injectors.—Strickland L. Kneass, Philadelphia.

This report, after discussion, was referred back to the Sub-Committee for the consideration of certain objections.

The following reports passed first reading:

Basin System.—C. L. Ricker, Newburgh, N. Y.

Letter and Document File.—Wm. H. Tucker, Newark, N. J.

Exhibit of the Pencoyd Iron Works, at the National Export Exposition.

Exhibit of A. J. Holman & Co., Philadelphia.

Exhibit of Laird, Shober & Co., Philadelphia.

Exhibit of U. S Geological Survey.

Variable-Speed Countershaft.—Milton O. Reeves, Columbus, Ind.

W.

SECTIONS.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, Tuesday, April 3d, 8 P.M.

This section organized by the election of the following officers: President, Dr. Henry Leffmann; Vice-Presidents, E. E. Ives and John G. Baker; Conservator, Dr. William H. Wahl; Secretary, F. M. Sawyer.

Mr. S. Ashton Hand read a paper, which was fully illustrated, on the making of lantern slides, with a series of very instructive illustrations. A communication was presented by Dr. Martin J. Wilbert on "Photographing Without the Aid of Light." Among the interesting experiments shown was one in which a coin was heated and then inclosed with a sensitive plate in such a way as to entirely exclude light, with the result of producing a negative in which the heat waves are supposed to have been the active agent.

Mr. John G. Baker exhibited on the screen some stereoscopic views by means of a special stereoscope which he had designed.

The regular meeting night was changed from the first Tuesday to the first Thursday of each month, the next meeting to take place on Thursday, May 3d.

F. W. SAWYER,
Secretary.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, Friday, April 6, 8 P.M. Dr. Wahl in the chair.

Mr. H. M. Watts made an informal address on "The Proper Organization of the Modern State Weather Service."

Mr. Watts reviewed the history of the various State weather services that have been organized with the co-operation of the United States Weather Bureau, devoting more especial attention to that of Pennsylvania, which, through the instrumentality of the Franklin Institute, was organized in 1857. It was one of the first and was conducted under the direction of the Committee of Meteorology of the Institute with the aid of an appropriation from the State for some eight years, when, owing to the failure of the State to make an appropriation, the work was taken up and continued by the United States Weather Bureau. Mr. Watts thought the time was now ripe for a concerted movement among the various scientific, technical and other institutions of learning of the State to take up the subject in a systematic way and build upon the present foundation a service for the State which with such co-operation could be made far more useful than it formerly was. He instanced a number of directions in which such a service might be extended with great advantage, especially to the commercial, agricultural and manufacturing interests. He cited the Maryland and Massachusetts State Weather Services as typical examples of what might be done in Pennsylvania by a properly organized and equipped establishment.

A lengthy discussion followed Mr. Watts' address, in which Mr. T. F. Townsend, Assistant in charge of the present State Weather Service; Professor Doolittle, of the University of Pennsylvania; Dr. Wahl, Secretary of the Institute, and others took part.

The subject was made a special order for the stated meeting in May.

W.

ELECTRICAL SECTION.—*Special Meeting*, held Tuesday, April 10, 8 P.M. Prof. W. S. Franklin in the chair. Present, 84 members and visitors.

Mr. Chas. F. Scott, Chief Electrician, Westinghouse Electric and Manufacturing Company, presented a paper on "Modern Central Station Practice." Mr. Scott pointed out that the word "modern" in this connection must refer to the last four or five years, as the "ancient" in central stations dates back only a score of years. The bitter controversy between alternating current and direct current which prevailed ten or twelve years ago has been renewed in another form. The direct current has had a fairly well-defined field in centers of cities, while the alternating current has not only found favor in towns and outlying districts where areas are wide, but has also been used extensively in city distribution as well.

In the new engineering which is made necessary by the extension and combination of electric interests, it is essential to generate power in large stations favorably located. Direct-current distribution therefore demands an alternating-current power station distributing to sub-stations, where the current is converted into direct current by rotary converters. The question then arises whether it is better to convert into direct current, or to distribute the alternating current without the intervening machinery with its inherent losses and the complication in operation which are involved if the current is converted into direct current. The various pieces of apparatus, including generators, rotary converters and motors, which are used in connection with the central station system were then taken up in detail. The most recent types of construction were illustrated and explained, and particular attention was given to those characteristics which are of particular engineering interest, and which bear particularly upon the choice between direct current and alternating current distribution.

In connection with the parallel operation of alternators, a mechanical analogue was presented in the form of two engines, which drive a common load through gear wheels which are connected with pinions on a common shaft, instead of alternators which are connected to common bus bars. It was pointed out that the operation of the engines, both as to the manner in which they may be first connected together, the conditions relative to division of load and to the shifting of load between the two engines are the same in most respects whether the engines be connected by gear wheels or alternators.

Some interesting facts respecting the operation of rotaries, particularly as to "hunting," were presented, together with the means which are effective in counteracting the various tendencies to this action. It was stated that the better class of rotaries are now operating with the same high standard of excellence which characterizes other types of electrical apparatus.

The old controversy between the induction and the synchronous motor is rapidly dying out, as there are few, if any, who advocate the synchronous motor for small work, while the dividing line in size between the field where induction motors are universally accepted and that in which there is still some difference of opinion is rising. Mr. Scott stated that he thought it quite certain that the induction motor would not wholly replace the synchronous motor, as there are some few conditions under which some of its features are of sufficient value to more than compensate for its many objectionable

elements. The adaptability of the induction motor to general service of a city where simplicity and reliability are of paramount importance was explained, and it was pointed out that while reliability rather than efficiency is the important element, yet the efficiency of the induction motor is practically the same as that of the direct-current motor at full load; it is higher at small loads, particularly in small sizes, where the brush friction of direct-current motors is comparatively high.

The characteristics of alternating-current apparatus make it in many respects the ideal form for use throughout the whole of a city plant. The difficulty which confronts the engineer at the present moment is the necessity of using the various existing apparatus in a comprehensive system, while at the same time he may be working forward to ultimately reach the system which will possess the greatest simplicity, reliability and economy in its operation.

The meeting passed a vote of thanks to the speaker of the evening and adjourned. W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday evening, April 11th. Mr. Joseph Richards in the chair.

Mr. Wm. R. Webster, Chairman of Committee No. 1 of the American Branch of the International Association for Testing Technical Materials, presented a report on the work that had been accomplished by this Committee. Advance copies of the specifications drawn up by the Committee are ready for those desiring to enter into the discussion of these in the fall.

Mr. Robert Job, Chemist of the Reading Railway, Reading, Pa., read a paper on "Railway Journal Bearings." He emphasized the importance of the proper structural arrangement of the metals in the composition, gave some good hints on the proper manipulation of this class of material in the foundry and described the causes prevalent in causing the so-called "hot box." The paper was well illustrated by a number of photographs and photomicrographs. The paper was discussed by Mr. Squire, of the Atchison, Topeka & Santa Fé R. R.; Mr. Brown, of the B. & O.; Mr. G. H. Clamer, the author, and others.

A vote of thanks was tendered Mr. Job for his interesting paper.

Adjourned.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, April 12th, 8 P.M. Prof. J. F. Rowland, Jr., in the chair.

Present, twenty-four members and visitors.

The topic for discussion, "Power Transmission by Belting, Ropes and Chains," was opened by Mr. Wilfred Lewis, who gave a general *résumé* of the subject, including the results of his own experiments on transmission by belting. He was followed by Mr. F. Barth, of Bethlehem, Pa., who entered more closely into the theory of leather belting, as deduced from practice in large machine shops and factories. Messrs. Spencer, Miller and Fullerton closed the discussion with a few remarks in reference particularly to rope drives and driving, and the proper designing of sheaves for that purpose.

D. EPPELSHEIMER, JR.,
Secretary.

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLIX, No. 6. 75TH YEAR. JUNE, 1900

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

ELECTRICAL SECTION.

Stated Meeting held Tuesday, November 28, 1899.

CAST WELD AND SURFACE CONTACT BONDS.

BY W. E. HARRINGTON,
Electrical Engineer, Member of the Section.

To determine definitely the electrical resistance of cast weld joints under various conditions with and without bonds, Wm. Wharton, Jr., & Co. kindly poured two joints around two pieces of 9-inch girder rail each 3 feet long. One joint was provided with flat copper bond made up of two pieces of copper, 4 x $5\frac{1}{2}$ x $\frac{1}{8}$ inches, securely contacted with the rail web upon each side of web, with iron plates 6 x $6\frac{1}{2}$ x $\frac{1}{2}$ held by four $\frac{7}{8}$ x $2\frac{1}{2}$ bolts, as shown in following sketches, *Figs. 1, 2* and *3*.

The cast weld joints were poured, having the general dimensions as shown in sketch, *Fig. 4*, two of the fish plate holes showing. The Weston milli-voltmeter was connected 24-inch centers upon head of rail, or 12 inches each side of joint.

The method of testing adopted was to obtain the drop in voltage or difference in potential around the various joints, the milli-voltmeter connections made upon 24-inch centers. The resistance in ohms of 24 inches of solid rail section was first obtained by measuring the drop in volts in 18 inches and reducing it to 24 inches. Weston instruments were used.

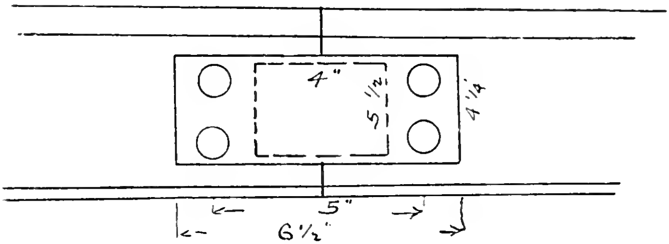

FIG. 1.

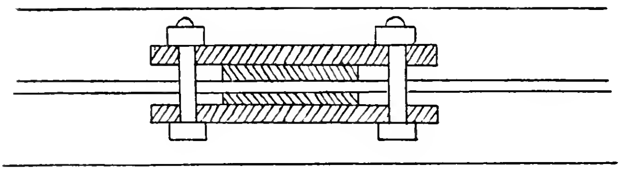

FIG. 2.

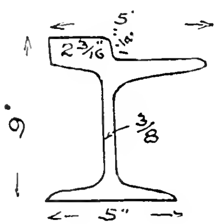

FIG. 3*a*.

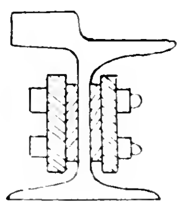

FIG. 3*b*.

The contacts of the milli-voltmeter were made through contacts made with Edison-Brown alloys. The resistance of the solid rail was used as a basis of comparison.

The tests were made by placing the rail with its joint in series with an ammeter, circuit breaker, switch and water rheostat and taking readings of the drop in milli-volts at each reading of current in ampères as shown upon ammeter.

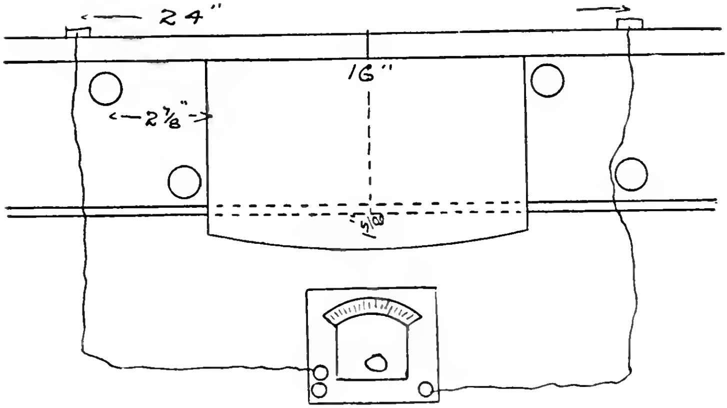
24"
16"
2⅞"
15/16

FIG. 4.

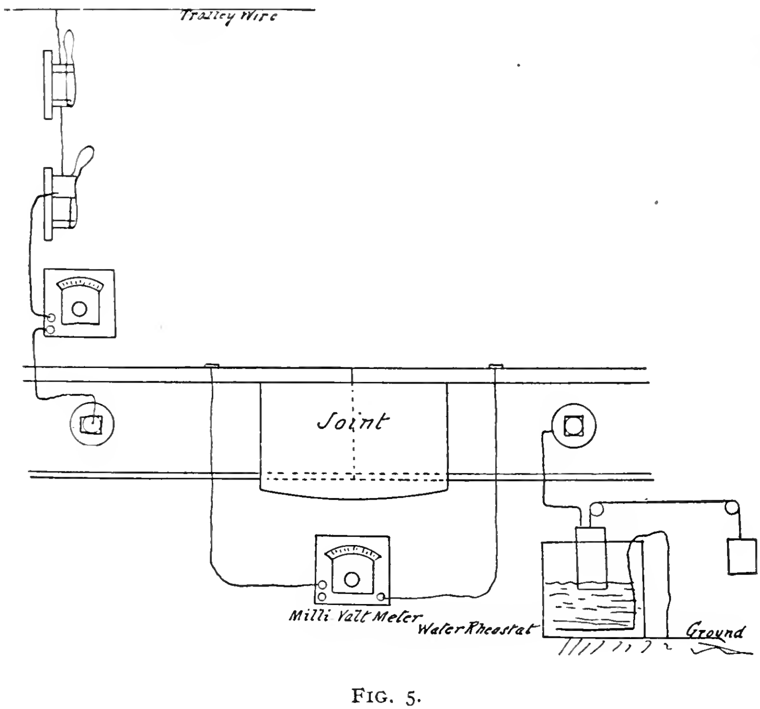
Trolley Wire
Joint
Milli Volt Meter
Water Rheostat
Ground

FIG. 5.

The foregoing diagram of circuit connections will show clearly the simplicity of the method employed, *Fig. 5*.

Herewith is a table of tests, with calculated results, showing resistance of 24 inches of solid rail:

RESISTANCE 9-INCH GIRDER RAIL. P. S. CO. SECTION No. 200.

Ampères.	Volts.	Ohms, 18 Inches.	Ohms, 24 Inches.
40	·00060	·000015	·000020
45	·00070	·000015	·000020
50	·00080	·000016	·000021
60	·00090	·000015	·000020
70	·00100	·0000143	·000019
80	·0012	·000015	·000020
90	·0014	·000015	·000020
100	·0016	·000016	·000021

Average resistance 24 inches = ·00002 ohm.

NOTE.—The above readings were calculated to compare with 2 feet of rail resistance, to compare with joint tests, which were made upon 18-inch basis.

Herewith is table of tests, with calculated results, showing resistance of a plain cast weld joint upon a 9-inch girder rail. Section No. 200, P. S. Co.

WITHOUT BOND.

Ampères.	Volts.	Ohms.	Remarks.
30	·0008	·000027	
35	·0009	·000026	
40	·0010	·000025	
45	·0011	·000024	
50	·0013	·000026	
55	·0014	·000025	Average resistance = ·000026 ohm.
60	·0016	·000026	
65	·0017	·000026	
70	·0019	·000027	
75	·0020	·000026	
100	·0027	·000027	

Herewith is a table of tests, with calculated results, showing resistance of cast weld joint with plates contacting with each side of rail, as shown above, as per sketch No. 1:

JOINTS WITH BONDS.

Ampères.	Volts.	Ohms.	Remarks.
30	·0012	·000040	
35	·0014	·000040	
40	·0016	·000040	
45	·0018	·000040	
50	·0020	·000040	
55	·0022	·000040	Average resistance = ·00004 ohm.
60	·0024	·000040	
65	·0026	·000040	
70	·0028	·000040	
75	·0030	·000040	
100	·0040	·000040	

Herewith is a table of tests, with calculated results, showing resistance of plain cast weld joint, supplemented with one complete "Bryan" bond 24-inch centers around the outside of joint. The Bryan bond consists of two 4/0 B. & S. gauge copper wire held between curved surface of bronze and malleable iron castings, the bronze casting contacting with a corrugated copper disk, which, in turn, contacts with a ground surface of rail web, all contacting surfaces being treated with Edison-Brown alloy.

The actual area of contact made by the Bryan bond upon the web of rail is difficult to determine, owing to the corrugation of the copper disk, although the plentiful use of Edison-Brown alloys would indicate a complete contact.

Ampères.	Volts.	Ohms.	Remarks.
40	·00070	·000017	
50	·00090	·000018	
60	·0011	·000018	
70	·0013	·000018	Average resistance = ·000018 ohm.
80	·0015	·000018	
90	·0017	·000018	
100	·0019	·000019	

A plain cast weld joint was taken and a hole ½ inch in diameter by ⅞ inch deep was drilled between the bottom rail ends down to the cast weld, as shown in following sketches, *Figs. 6* and *6b.*

The metal was so hard the drill would hardly cut it; the drill was run, using soda water as a lubricant. The hole was cleaned out and thoroughly amalgamated with Edison-Brown alloys, and finally filled up to the surface with Edison-Brown flexible solder. The result of the test, showing

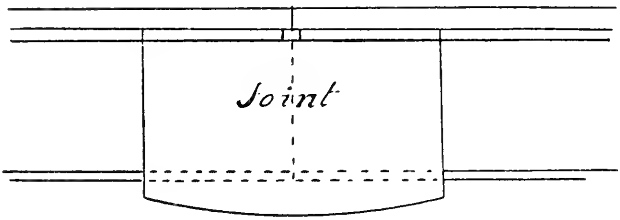

FIG. 6.

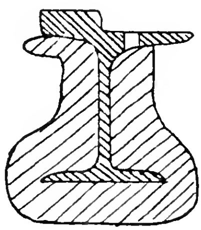

FIG. *6b.*

the drop in voltage and ohmic resistance, is shown in the following table:

Ampères.	Volts.	Ohms.	Remarks.
30	·0006	·000020	
40	·0009	·000022	
50	·0011	·000022	
60	·0013	·000022	Average resistance = ·000021 ohm.
70	·0016	·000021	
80	·0018	·000022	
90	·0020	·000022	
100	·0022	·000022	

The plain cast weld joint was again taken, the amalgam removed from hole and a piece of sheet copper 30 inches long by 4 inches wide by $\frac{1}{8}$ inch thick with two $1\frac{1}{16}$-inch holes punched therein was placed to go around the cast weld joint and contact with the rail web in the same holes that the test had been made previously, with the Bryan bond upon 24-inch centers, the contacts were thoroughly amalgamated with the Edison-Brown alloys.

Washer plate 4 inches square was used with 1-inch bolt and lock washer to hold each of the two ends in form and positive contact with the rail web.

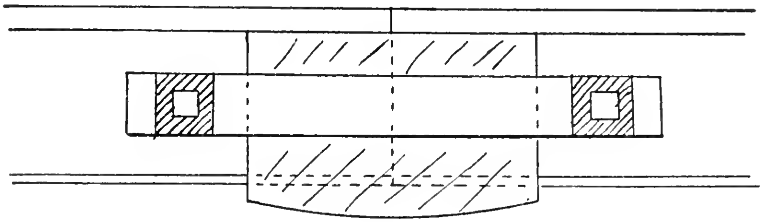

FIG. 7.

Herewith is a sketch of the connections and form of bond, *Fig.* 7.

The area of contact upon each of this bond is 15 square inches.

Herewith is table showing the results of the ohmic resistance and voltage.

Ampères.	Volts.	Ohms.	Remarks.
30	·0004	·000013	
40	·0006	·000015	
50	·0008	·000016	
60	·0010	·000016	Average resistance = ·000016 ohm.
70	·00128	·000017	
80	·00130	·000016	
90	·00150	·000016	
100	·00160	·000016	

CAST WELD JOINT ELECTRICAL TESTS. SUMMARY OR COMPARISONS OF TESTS.

Test.	Ohms.	Percentage Comparisons of Resistance of each Test with the Resistance of Solid Rail Resistance.	
		Per Cent. Less	Per Cent. Greater.
Solid rail	·000020	—	—
Plain cast weld	·000026	—	30
Cast weld with copper contacts, *Fig. 1*	·000040	—	100
Plain cast weld with 2—4/0 Bryan bond	·000018	10	—
Plain cast weld with ½ x ⅞ Edison-Brown alloy plug	·000021	—	5
Plain cast weld with 30-inch x 4-inch x ⅛-inch sheet copper outside	·000016	20	—

Herewith is a copy of a letter from Messrs. Wm. Wharton, Jr., & Co. as to the composition of the cast iron in the joints:

PHILADELPHIA, June 3, 1898.

Subject—Recomposition of iron in test joints.

MR. W. E. HARRINGTON,

General Manager Camden and Suburban Railway Company.

DEAR SIR:—Referring to the matter of the composition of the cast weld joints made for your experiments day before yesterday, we beg to say that the joints were run in with other work, and no record was kept of what heat they were taken from, but to the best of our judgment the following would be the result of an analysis of this metal:

Iron	92·66
Combined carbon	·30
Graphite	3·45
Silicon	2·25
Sulphur	·04
Phosphorus	·70
Manganese	·60
Total	100·00

Trusting this will answer your purpose, we remain,

Very respectfully,

WM. WHARTON, JR., & CO., INCORPORATED,

(Signed) A. B. KIBBE,

Engineer of Construction.

TRACK TESTS OF JOINTS.

Various attempts were made to test joints in street by using a water rheostat and making connection to overhead trolley, assuming that current would flow through joint either from or to the power station according to the manner the power station is connected.

The results obtained from this method were of such a variable character as not to be depended upon, owing to the uncertainty of the amount of current flowing through the joint.

The only tests which gave correct results, under the above conditions, were those made upon the last joints at extreme ends of line.

In this connection it is interesting to note the tests made

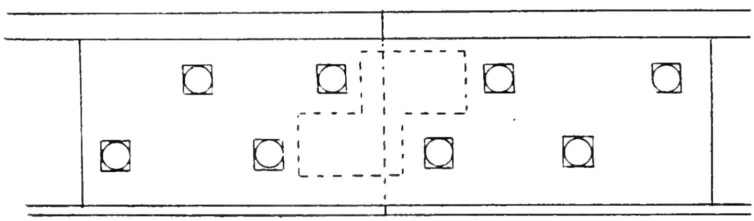

Fig. 8.

under the latter condition upon 7-inch girder rail, Pennsylvania Steel Company's Section No. 238, with an eight-bolt, 26-inch fish plate, using Ajax bond, as per sketch, *Fig. 8.*

Herewith is schedule of tests :

Ampères.	Volts.	Ohms.
20	·0004	·00002
30	·0006	·00002
40	·0008	·00002
50	·0010	·00002
60	·0012	·00002
70	·0014	·00002
80	·0016	·00002
90	·0018	·00002

The above tests were made with the Weston milli-volt-meter connected upon 24-inch centers.

The remarkably good results obtainable from the use of the large, broad area of contacts in the sheet copper bond employed around the cast weld joint emphasized the correctness of the use of the sheet copper contacts for bonding purposes under fish plates, when such construction was used.

Various bonds were made up to suit the requirements

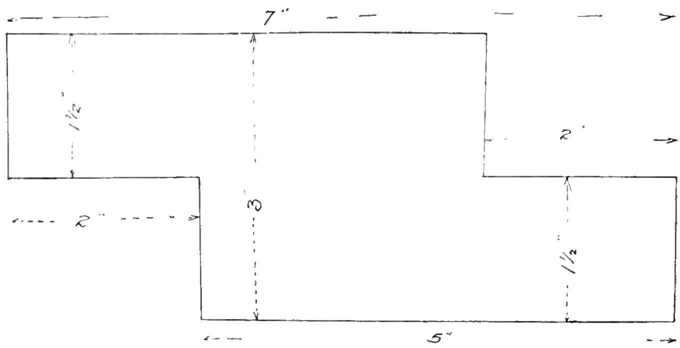

FIG. 9.

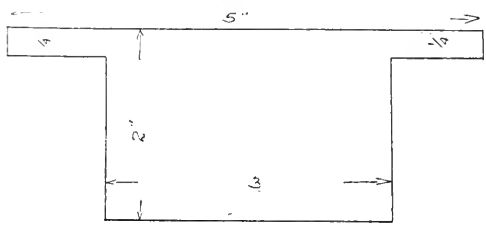

FIG. 10.

of different rail sections, fish plates and drillings. Herewith are dimensional sketches of several sizes:

Ajax bond for 7-inch girder rail, Cambria Iron Company's section No. 824, under 26-inch-long fish plates, staggered bolts, *Fig. 9.*

Ajax bond for 7-inch girder rail, Pennsylvania Steel Company's section No. 238, under 26-inch fish plate, six bolts, *Fig. 10.*

Ajax bond for 9-inch girder rail, Pennsylvania Steel Company's section No. 200, under 32-inch fish plates, twelve bolts, *Fig. 11*; also *Figs. 11b, 11c, 11d.*

The Ajax bonds, as illustrated above, consist of a piece of copper pressed against the abutting rail ends through the medium of cupped ½-inch set screws bearing against a

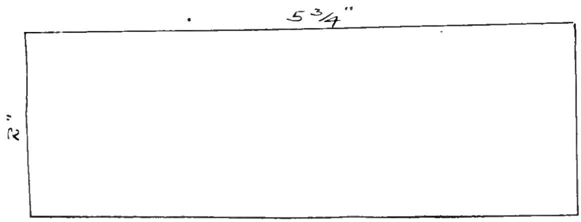

FIG. 11.

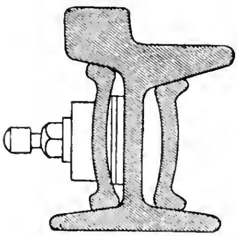

FIG. 11*b*.

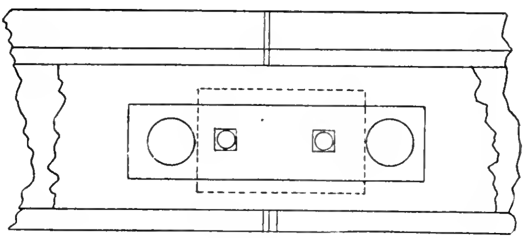

FIG. 11*c*.

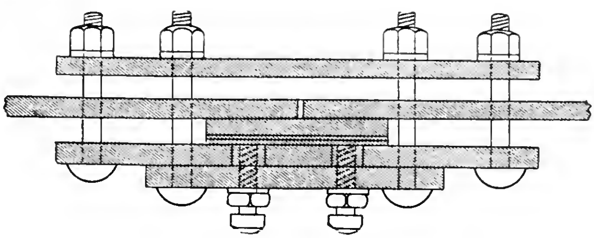

FIG. 11*d*—Special form illustrating Ajax Bond.

thick superimposed piece of steel to divide and distribute the pressure.

The rail is ground off, exposing a clean metallic surface, and then treated with any practicable mercuric compound to amalgamate the rail to prevent oxidation.

Repeated tests were made upon the above sizes, and the average of the results is shown in the large schedule of tests.

The conclusion to be drawn therefrom is quite interesting. It shows that the ohmic resistance is quite comparable with the resistance of the rail section itself, and, if

	Kind of Bond.	C. to C. of M. V. Contacts.	Center to Center of Contact.	Length of Bond.	Size of Contact.	B. & S. Gauge.	Number of Wires in Bond.	Ohms.
Penna. Steel Co. 7" Girder Rail No. 238	Joint only, no bond	36"	36"					·00071
	Iron channel pin	36"	45"	48"	$\frac{9}{16}$" pin	0	1	·00049
	Bryan iron wire	36"	36"	39"	Plate 2¾" dia. 1" hole in it	½"	2	·000286
	Crown	36"	30"	36'	⅞" head	0000	1	·000247
	Bryan iron wire, amalgamated	36"	36"	39"	Plate 2¾" dia 1" hole in it	½"	2	·000224
	Crown, amalgamated	36"	30"	36"	⅞" head	0000	1	·000185
	Bryan copper wire	36"	36"	39"	Plate 2¾" dia. 1" hole in it	0000	2	·000175
	Columbia	36"	30"	36"	⅞" head	0000	1	·000131
	Columbia, amalgamated	36"	30"	36"	⅞" head	0000	1	·000126
	Stranded crown	36"	5"	7"	⅞" head	0000	1	·0001
	Plastic socket	36"	3½"					·000093
	Bryan copper wire, amalgamated	36"	36"	39"	Plate 2¾" dia. 1" hole in it	0000		·000071
	Plastic cork	36"	9"		Surface 1¼"			·00006
	Ajax bond	24"	24"	8½"	8½ sq. ins.	¼ sq. in. section		·000041
	Solid rail, no joint	24"	24"					·000024
No. 55 Wharton	Joint only, no bond	24"	24"					·0015
	Ajax bond	24"	24"					·000048
	Solid rail, no joint	24"	24"					·000035
60 lb. T.	Double Ajax	24"	30"					·00004
	Solid rail, no joint	24"	30"					·000035
35 lb. T.	Ajax bond	24"	24"					·000051
	Solid rail, no joint	24"	24"					·000044
9" P.S.Co. Sec. 200	Ajax bond	24"	24"	5¾"	5¾ sq. ins.	⅜ sq. in. section		·000031
	Solid rail	24"	24"					·00002

double bonding be employed, the resistance can be made less than rail resistance with far more certainty of result than that obtainable from any of the types of bonds expanded in the holes in foot or web of rail.

The features in the bond are such that they commend themselves at once, owing to ample and liberal contacts, adjustable means for renewing contact, the knife blade switch type construction and the absolute freedom from the inevitable loss or breakage, with consequent "scrapping" of bonds, so frequent in all the other types employed.

The writer has found that the total cost from placing the sheet copper bonds has always been less than placing the other makes.

The large rail manufacturers have always finished the fish plates properly drilled and tapped ready for placing the bonds.

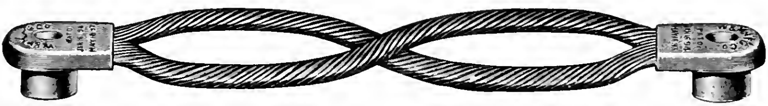

FIG. 12.

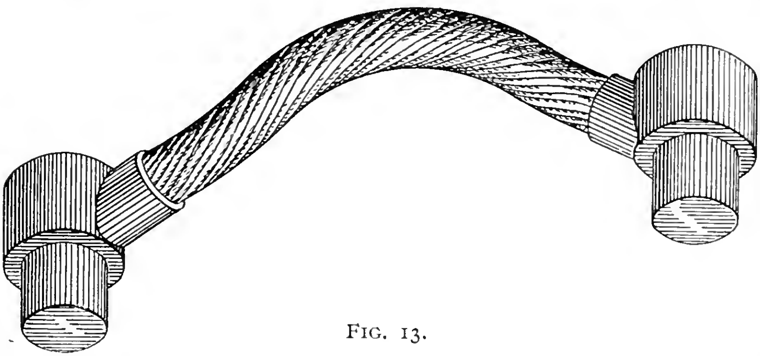

FIG. 13.

Herewith is a schedule of tests made upon different bonds, and in each instance is the average of large numbers of tests:

Figs. 18, 18b, 18c, 18d, 18e illustrate the most recent form of Edison-Brown bond located under fish plate, but depending upon the Edison-Brown alloys for contact.

CONCLUSIONS.

(*a*) The cast weld joint alone has a resistance 30 per cent. greater than the solid rail section.

(*b*) The use of sheet copper, as furnished by the Ajax Company, makes the combined resistance 20 per cent. less than the solid rail section.

(*c*) Where the cast weld joint is not employed and the usual fish-plate form of construction adopted, the flat sheet surface contact form of bond, known as the "Ajax," makes

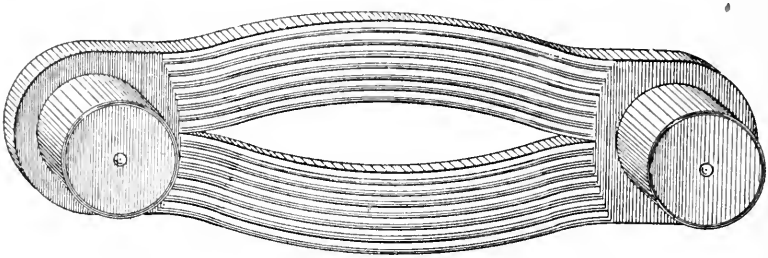

FIG. 14.

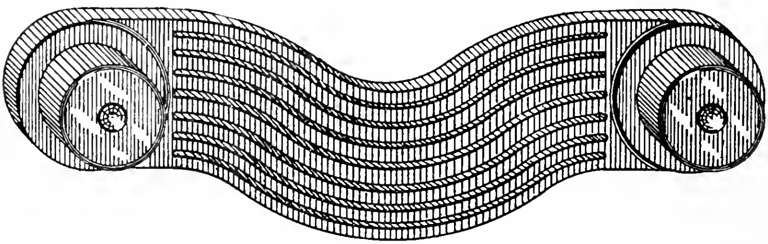

FIG. 15.

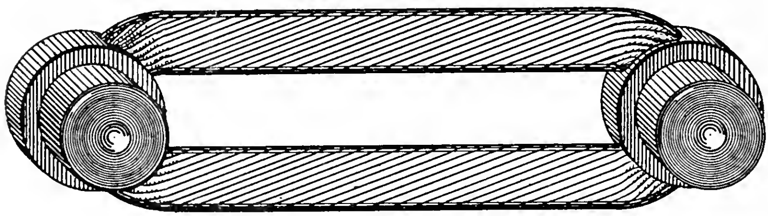

FIG. 16.

the most efficient type of bond, both electrically and mechanically, making resistance only slightly more than the rail section against the other types of bonds, as shown on table of tests, whose resistance runs from three to four times more.

General.—The trend of practice has been during the last year or two to use a form of bond to be placed under the fish plate, instead of around the outside of the fish plate.

In the types which have heads *riveted* or *expanded* into the rail the leads are made flexible to provide for rail movement, caused by expansion and contraction and vertical movement of rail following the passage of cars over joints.

Herewith are shown cuts illustrating some of the types most frequently used, *Figs. 13, 14, 15* and *16.*

As mentioned above, tests have demonstrated that the bonds making *superficial contact* with the web of the rail instead of contacting with the side of a hole through the web are the most efficient and economical design.

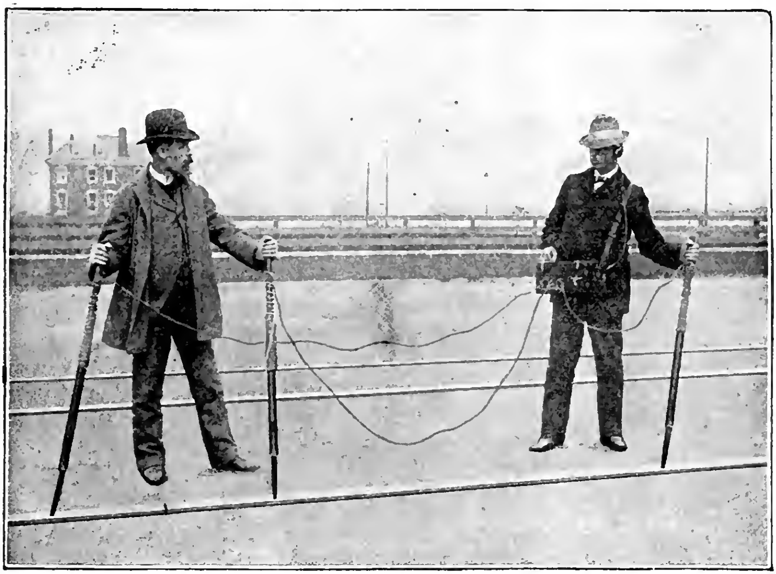

FIG. 17—The Conant rail-joint testing instrument.

There is a battle royal raging between the exponents of the hole type as to what constitutes the best method of preparing the hole and placing the bond.

One concern punches out the hole with a hydraulic press and places the bond head in the rough irregular hole and expands the bond head by similar means in the hole, whilst an engineer in New York goes so far as to drill the hole, then ream, followed by pressing hardened steel balls, through a hole in bond in order to provide an accurate fit.

Fig. 18.

Fig. 18*b*.

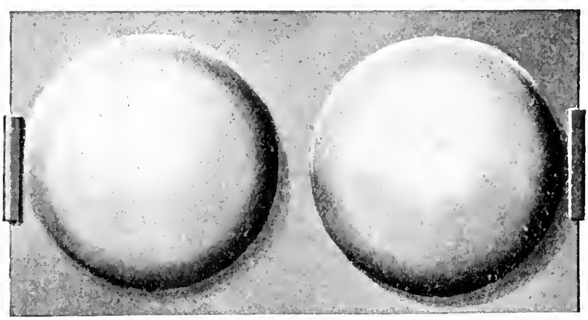

Fig. 18*c*.

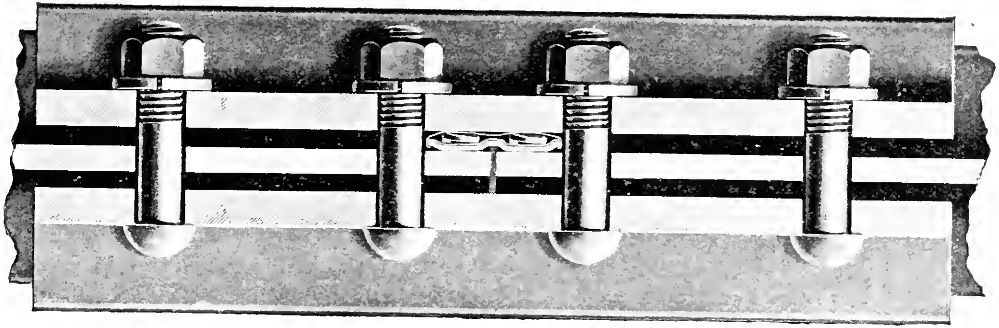

FIG. 18*d*—Illustrations of the most recent forms of the Edison-Brown mercury type of bond.

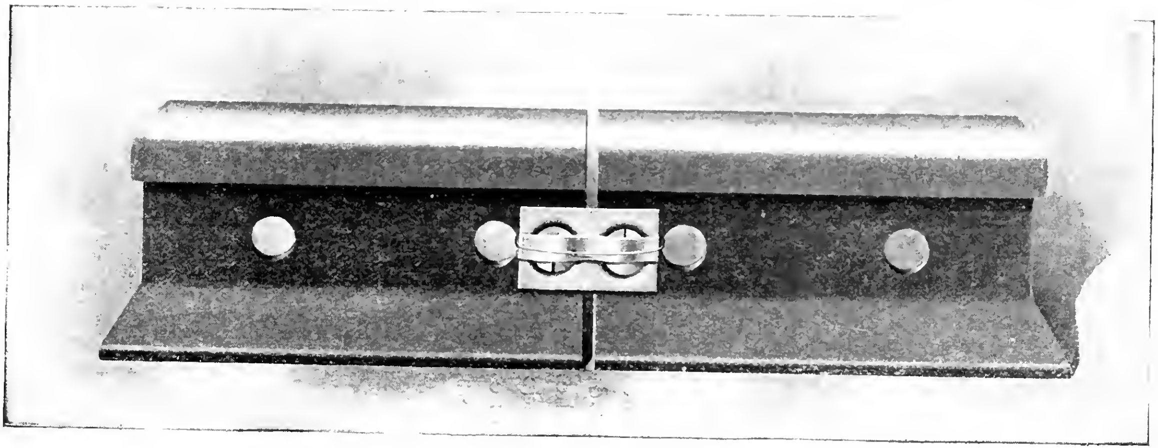

FIG. 18*e*—Illustrating Edison-Brown mercury bond.

Testing.—As to testing rail bonds, practical tests after rails and bonds are placed are exceedingly difficult and unsatisfactory, owing to various factors which interfere in obtaining uniform readings. Our experience has been to test the bond carefully under laboratory conditions and then watch the bond while in practical use over a long period of time as to mechanical or physical changes.

Herewith is shown a cut of a device, *Fig. 17*, advertised as being a practicable, testing device, probably within ordinary requirements will give a means of roughly determining the relative relation of resistance of bond to that of rail in terms of length of rail. The principle is that of comparing by the "null" method of measurement, using a telephone to determine the resistance of the joint to such a length of rail that the rail resistance will balance the bond resistance.

NUMBER OF BONDS TO BE PLACED.

The question has often been discussed as to what extent bonds should be placed. Some contend to place bonds so the conductivity of the joint will be equal to the rail section. Others contend that the conductivity be made equal to the feeder system. Others again contend that the bonding be done to provide for the flow of current through joint, the joint is calculated to carry under normal conditions, basing the carrying capacity of copper as 1,000 ampères per square inch of cross-section, and 100 ampères per square inch of contact.

The writer believes the latter method the best under ordinary conditions, as the first method, while theoretically the best, still is almost impossible to pursue in all cases for various reasons, such as the cost, mechanical difficulties, etc. Where cast weld joints were employed the writer, however, was successful in making the resistance of the joint actually 20 per cent. less than the resistance of a corresponding rail length.

CARRYING CAPACITY OF RAILS.

The cross-section of standard girder rails is closely approximate, the same number of square inches as the rail

is high; for instance, a 7-inch girder has a cross-section of 7 square inches, a 9-inch girder, 9 square inches.

As the conductivity of copper is to iron in the ratio of approximate 7 to 1, it follows that a 7-inch girder rail has the conductivity of 1 square inch of copper, while a 9-inch girder has the conductivity of $1\frac{2}{7}$ square inches of copper, and the two rails of such a track would have a conductivity of $2\frac{1}{2}$ square inches of copper. One can readily see to attempt to bond to the carrying capacity of the rail would be an exceedingly expensive undertaking. Of course it may be necessary upon the trackage approaching the power station.

Read at the stated meeting held November 28, 1899, and discussed at the stated meeting held February 27, 1900.

INCANDESCENT LAMPS.

By Francis W. Willcox.

(*Concluded from page 369.*)

CANDLE-POWER PERFORMANCE.

Tests of this character have frequently been made, but not always with a regard to the necessities of the case. Curves of candle-power have often been published without any statement of the efficiency at which the lamps were started.

This is of the first importance—to have the efficiency definitely known and accurately determined to within $\frac{1}{10}$ of a watt. It is not generally appreciated how important this is. A difference of $\frac{1}{10}$ of a watt per candle is sufficient to make a difference of 100 hours of life performance. Therefore in testing it is a prime requisite to have lamps under test start at an exact equality in average efficiency. If the lamps pass the initial test as to close rating, then the number to be set up for life test can be selected so as to average the desired efficiency. For example, in the case of lamps on diagram, *Fig. 2*, we would select for test those along the 3·1-watt line. The economy chosen as a basis for

test is generally the highest possible, as this shortens the period of test. For this reason 3·1 watts per candle is preferable, as test need not be continued longer than 400 hours, while with 3·5-watt lamps the period would be over 600 hours, and with 4-watt over 1,200 hours.

Not only must economy be exact, but the candle-power and voltage must be similar. It will not do to compare 50-

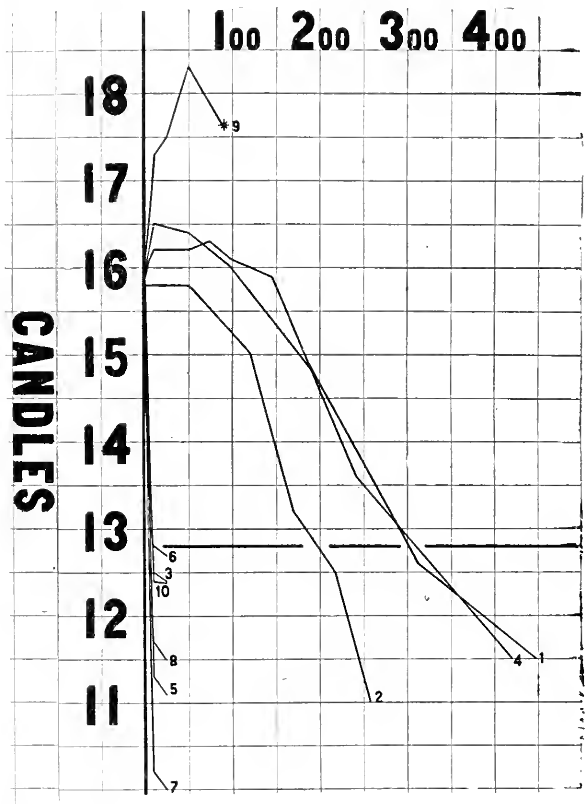

FIG. 6.—Candle-power performance diagram, showing poor results given by ten 16-candle-power 100-volt lamps—3½-watt lamps.

volt lamps of one make with 100-volt of another, or 10 candle-power with 16 candle-power.

The number of lamps to be tested should preferably be twenty-five or more of each make, and never less than ten. Any less number is not sufficient to give a safe average.

The voltage during test should always be kept normal and constant. An average increase of but 1 volt in pressure during test will decrease the result 10 per cent., and a volt decrease in pressure will increase results in same ratio.

The candle-power readings may be continued indefinitely, but the practical method is to continue results to some

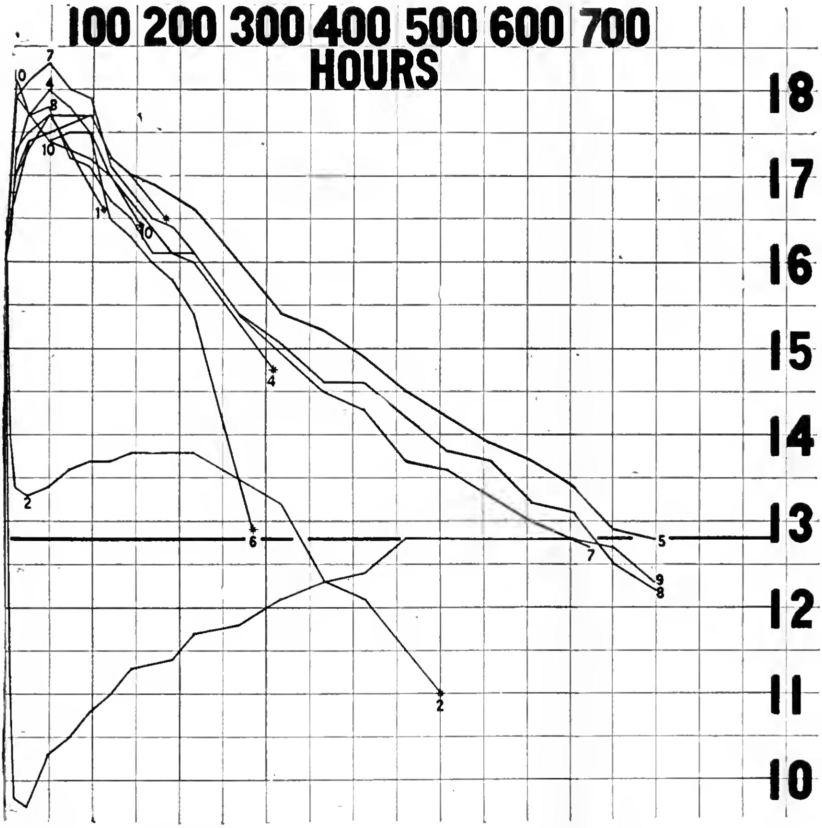

FIG. 7.—Candle-power performance of ten lamps, 16 candle-power 112-volt 3½-watt lamps, showing lack of uniformity in performance.

agreed limit of comparison. The limit most generally taken is 80 per cent. of the initial candle-power, which would be, for the 16 candle-power lamp, the 12·8 candle-power line.

Here are several sets of candle-power tests* plotted on diagrams in the usual manner, with the ordinates representing candle-power and the abscissæ hours of burning. An examination of these will show us some features of interest.

Diagram, *Fig. 6*, shows the miserable results some makes

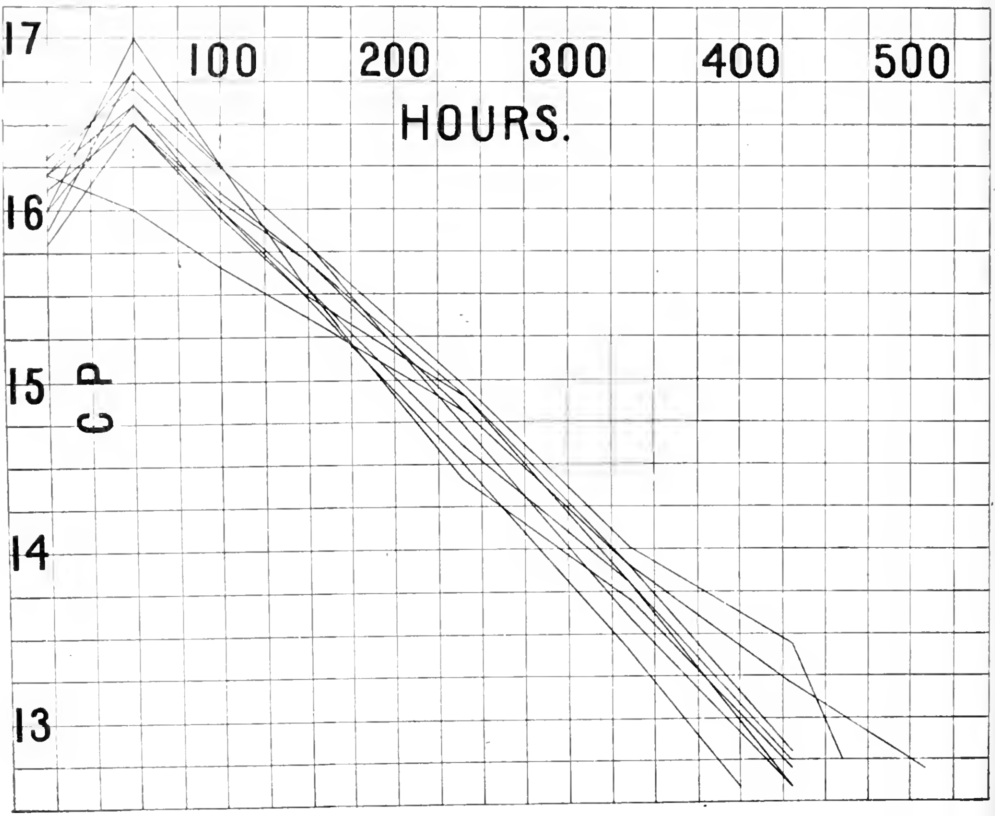

FIG. 8.—Candle-power performance of ten 16 candle-power 112-volt 3·1-watt lamps, showing uniform and good results of well-made lamps.

of lamps will give. Here are ten lamps set up at an average economy of 3·5 watts per candle, and six of them lost over 20 per cent. in candle-power inside of ten hours, only three lamps giving any life at all. Such a lamp no station could

* The writer wishes to acknowledge indebtedness to the Association of Edison Illuminating Companies for many of the diagrams used herein.

afford to use even if a bonus were paid on each lamp. Yet the manufacturer of this lamp glibly made a contract with the United States Government to furnish lamps under specifications that not more than three manufacturers in the world could regularly fulfil.

Diagram, *Fig. 7*, exhibits an interesting set of curves of ten lamps started off at 3·12 watts per candle. This illustrates the bad effects of a rise in candle-power at starting. Owing to this rise in candle-power, readings should be taken every 25 hours for first 100 hours. All lamps rise some at the start, but this rise should be limited, as, in excess, it strains the filament and causes early breakage, as is here well exemplified. Two of the lamps slumped badly, and one of the curves shows a curious recovery feature, regaining three candles to 13 candle-power, after having dropped to 10 candle-power. This is a freak of performance that has been considered impossible, but it is quite often met with in lamp testing. The explanation of this is that the filament of the lamp had a discolored or blackened surface (through bad vacuum), and, as such a surface is a poor radiator of light, the candle-power declined very rapidly for the first twenty hours, as shown. The vacuum improving as the lamp continued to burn, the sooty, discolored coating on the filament was burned off. This made the filament a better radiator of light, and so caused the subsequent rise in candle-power shown.

It will be noted that in all these diagrams the individual curve of each lamp is plotted. This serves to illustrate the degree of uniformity of performance, and is a great improvement upon the old methods of averaging results and plotting only one curve.

In diagram, *Fig. 8*, we have a set of curves showing how well-made lamps should perform—illustrating good results and great uniformity.

Compare this with *Fig. 9*, showing results on ten lamps taken at random from a barrel sold for 16 candle-power 3·1 watts per candle, an excellent example of poor results.

A proper measure for lamp value should include both

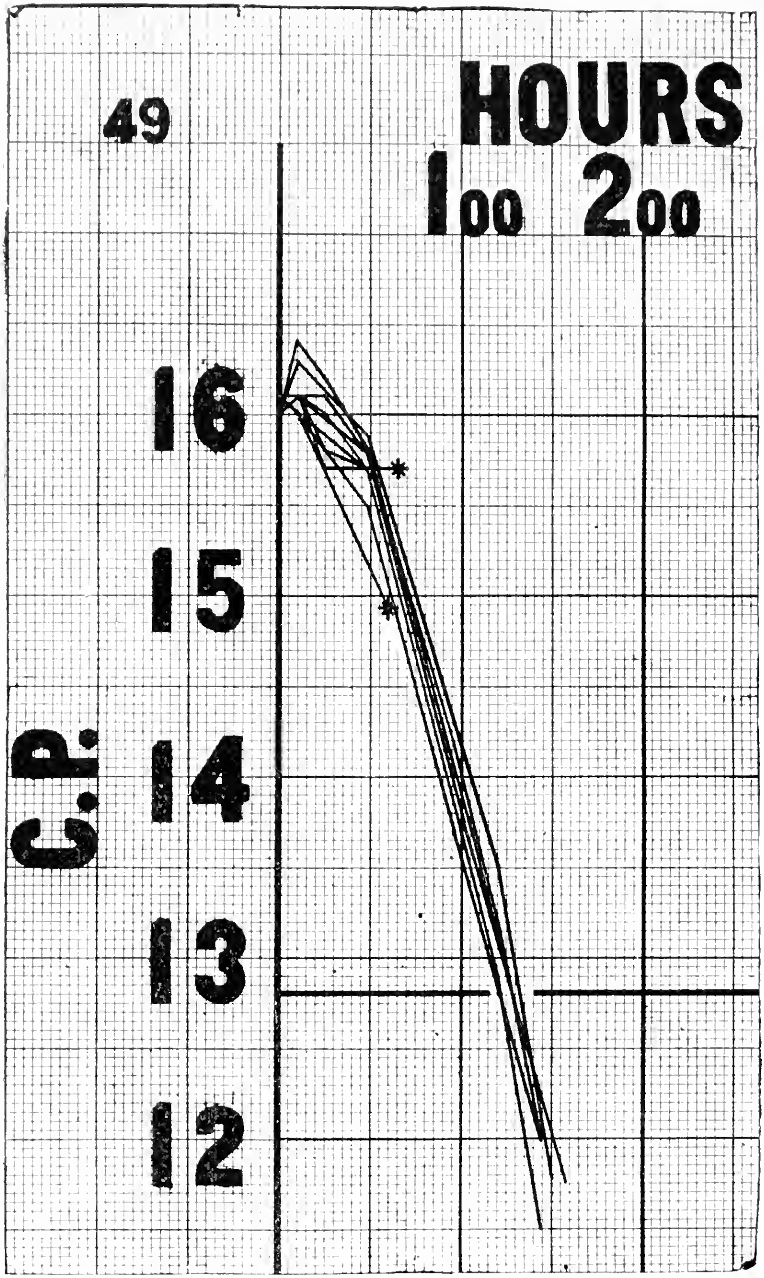

FIG. 9.—Candle-power performance of ten 16 candle-power 115-volt 3·1-watt lamps, showing rapid decline of candle-power.

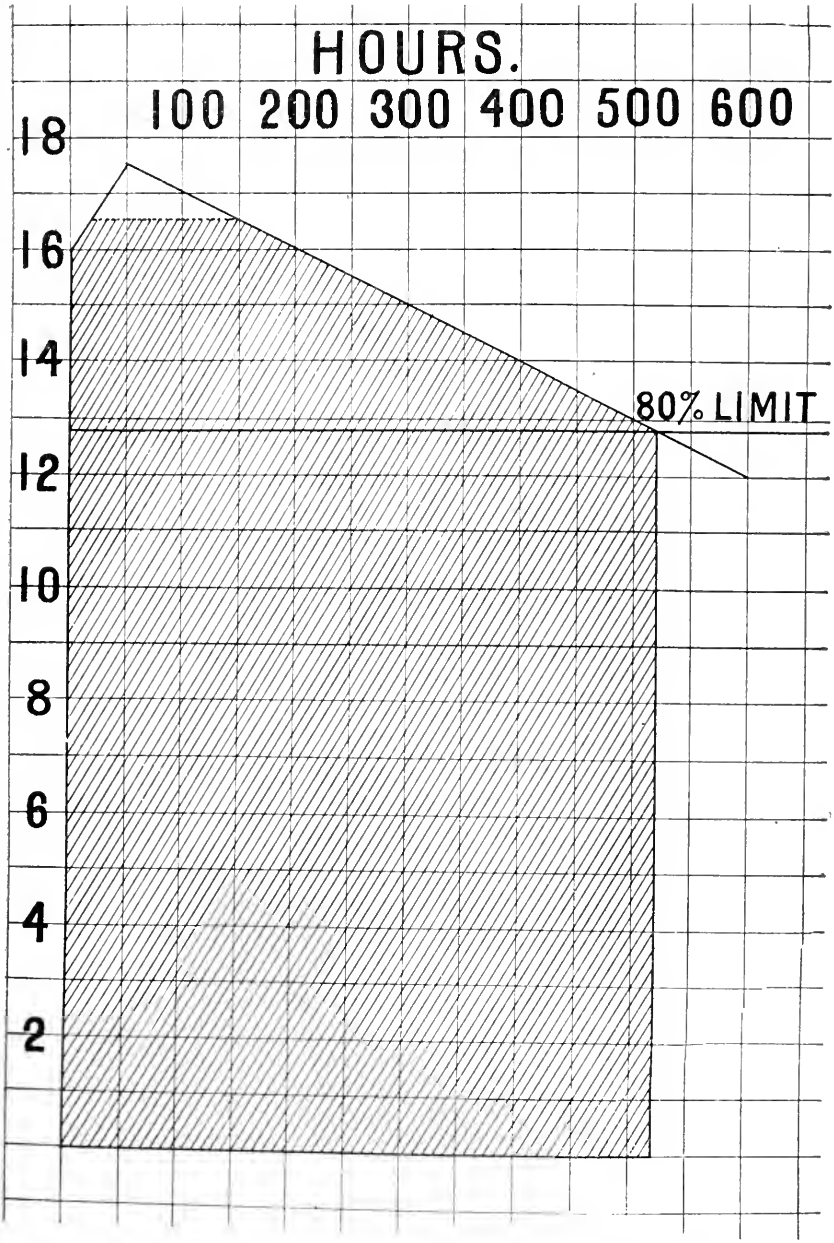

FIG. 10.—The candle hour area. The measure of lamp value.

life and candle-power results. Such a measure is the candle hours of life given by a lamp to an agreed limit of candle-power. The limit agreed upon is 80 per cent. of initial candle-power. The graphic expression of this measure is the area bounded by the average candle-power curve and a vertical line drawn from intersection of curve and 80 per cent. limiting line. This area is shown on diagram, *Fig. 10*, and is called the candle hour area.

The part of this area below the 80 per cent. line forms a constant quantity, and it would be better were this omitted and only the area above the 80 per cent. line, or "top area" as it is called, taken. It is this "top area" which measures the useful results, and much more determinate comparisons can be made on it as a basis of value than on the full area.

It is pertinent to also note that with normal lamps the candle hour area is directly proportional to the useful life, so that the useful life can be used as a definite basis for specifications and guarantees.

As regards candle-power performance, customers should purchase their lamps under specifications requiring a minimum number of candle hours or a minimum useful life as the average results for the principal types of lamps used and exacting a penalty of a sufficient number of lamps or the money value thereof to make up any deficiency between guarantees and actual performance, as determined by tests of samples taken from each lot of lamps.

Regarding specifications in general there is much that is objectionable in their practical application to lamp purchase and supply. The incompetent manufacturer will quite glibly bid under any set of specifications either through ignorance of what he can do or trusting to luck to get around the requirements. He can hardly be blamed for running the chances, considering how seldom complete checking tests are made of lamps purchased. Let a consistent invariable course be followed of testing lamps before they are accepted for use and of rejecting every lot that falls below requirements, and the incompetent manufacturer will soon be brought to table. This has been the policy of the U. S. Navy, and it is a well-known fact that

numbers of manufacturers have learned to their cost that they dare not bid to supply lamps to the navy.

The navy keeps a sufficient stock on hand to supply running needs and tide them over the delay due to the rejection of any lot purchased.

These conditions are, however, not to be found in the case of the average purchaser, and other methods are necessary. The best and most practical method, it seems to me, was the one adopted by the Standard Oil Company, of New York. This company last winter purchased in the open market some fifty lamps each of a dozen of the leading makes and carried out a complete test thereon. This gave them positive data as to what lamp gave best results, and the difference in value between it and the next best. With this information in hand the selection of the lamp to be purchased was readily and intelligently made.

This suggests the best plan for the general purchaser. Let him determine, by test of the average product of different makers, the best make and type of lamp suitable for his service. Then let him buy the lamp thus selected, under specifications and guarantees, testing samples from each lot of lamps received, and holding the manufacturer closely to his guarantees.

DISCUSSION.

PROF. ARTHUR J. ROWLAND:—In most papers on incandescent lamps we find them treated from the standpoint of their candle-power, some peculiar or abnormal effects in them, their advantage as compared with other sorts of illuminants. Or, we listen to descriptions of special systems of lighting, or to accounts of instruments and apparatus made to test incandescent lamps. Here, in Mr. Willcox's paper, we have one giving a view of another side of the subject, the one on which we electrical people know too little. We do, indeed, know that some lamps prove unsatisfactory in this or that way, without being able to see or tell why they are so; that others are eminently satisfactory, but have no direct means of knowing whether this lot of lamps is good because they happened so, or whether

they represent a really steady process of manufacture. We know how, or think we know how, to test incandescent lamps; but need and welcome all the suggestions we can get from the people who make the lamps and who therefore know better than any one else what they can or cannot be expected to do.

To me the flashing of modern incandescent lamps has always been a most interesting process, both as to details of method and as regards the results procured. Here are the carbonized cellulose filaments, sooty in surface and sometimes of irregular resistance and spotty when current passes through them. They are put into gasoline vapor, a current turned on and the resistance drops as a tube of graphitic carbon deposits around each carbon filament until, the desired resistance having been reached, the circuit is automatically opened.

If the sooty surface filament had been put into a bulb and the combination made into an incandescent lamp, the life of the lamp would be short, the candle-power would rapidly drop, the efficiency be low (for the sooty surface is a good heat radiator) and the bulb be very hot. With the filament flashed, the candle-power and efficiency are well maintained through life, a high efficiency becomes possible, and the only disadvantages are the initial rise in candle-power and the readiness with which the filaments are strained by excessive voltage.

Every one should know that not only can one tell a graphite-covered filament by looking at it, as Mr. Willcox has explained, for its bright steely surface is very easily recognized, but one can tell whether there is much graphite on the filament or not by noting whether the filament is long for the voltage, candle-power and efficiency marked. The graphite deposit has a considerably lower specific resistance than that of the core ($\frac{1}{6}$ to $\frac{1}{7}$ as much), and, if much of it has been deposited, the filament must be long to get the required resistance. If there is plenty of graphite, we expect long life and maintained candle-power.

It has come to be the practice of lamp manufacturers to make tests of lamps to prove that they have the requisite

vacuum by connecting with a suitable induction coil and observing the absence of a glow in the lamps when they are being tested, and Mr. Willcox recommends the same test to users of lamps, to measure (in one respect) the value of lamps purchased. I suppose the manufacturers know how important the high vacuum is, but it is difficult for some of us to forget how some of the best lamps on the market a few years back (infringing lamps though they proved to be) were lamps in which the vacuum was low, an inert gas having been introduced at the last part of the exhausting process. I have some doubts, then, whether the spark-coil test may not work hardship on some real good lamps if the fact that they show a glow under the induction-coil test is to be taken as evidence that they are to be rejected. For high-voltage lamps in which the Edison effect is liable to be great, and so produce trouble at the leading-in wires, doubtless a high vacuum is essential, as distinguished by an absence of blue glow in the bulb when first burning or the absence of any glow under the induction-coil test.

Mr. Willcox tells us that the limits allowed for good 16-candle-power lamps in a specification for lamps need only be $\frac{1}{2}$ candle-power each side of that and $1\frac{1}{2}$ watts each side of the rated watts of the lamp. I have tried a good many lamps, and may, at least, express the opinion that limits as I have assigned them below are entirely satisfactory, and there are few lots of lamps taken from stock on the open market, of even the best makes, that will satisfactorily stand a closer test. These requirements are:

A 16-candle-power lamp is understood to be one which, when rotating on a vertical axis at 180 revolutions per minute, measures not less than 14·5 candle-power and not more than 17·5 candle-power as its mean horizontal candle-power.

A lamp is of satisfactory efficiency if it does not differ from its rating more than $\frac{2}{10}$ watt per candle-power.

I agree thoroughly with Mr. Willcox's statement that lamp tests are of small account unless a reasonably large number of lamps be put on test. It has been such common practice to put three lamps on a life test and draw con-

clusions from the performance of these that a test in which ten or more are taken looks very formidable. Certainly such a test is too much of an undertaking and too much expense is involved, too, to make it one which is likely to be made by the user of lamps in an ordinary isolated lighting plant. General tests, however, are not of much value to separate plants. The results of a test made on lamps on the circuits of one station will scarcely correspond with those made on another. The differences in regulation, the differences in actual average E.M.F. on the lamps will make quite a little difference in the results procured. I have examined into this by trial to some extent, and hope to find out more about it in the future. Results of general tests, then, show simply that certain lamps are good and certain ones are bad—scarcely that one make of lamps is 10 per cent. better than another because 10 per cent. more candle hours were had from it than from another.

A word regarding the fluctuations in candle-power values along candle-power curves. Not many months ago I would have attempted to prove in argument that after the initial rise, when the candle-power had really begun to drop, it would continue to do so, and any rise in candle-power observed was a sure indication of a false photometer reading. Now, I must acknowledge that there are sometimes curious "lumps" in the candle-power curve which must be due to real changes in the candle-power of lamps. But the man who is measuring candle-power had better beware of these as suspicious, especially if he has no rotating socket to use in making his tests. For that matter, a determination without a rotating socket cannot amount to much anyhow, and photometers in which they are absent are of little account. I have so often seen irregularities in candle-power curves really due to matters of small account seemingly, which were overlooked in making measurements on account of the inexperience of the observer, that I feel very confident in what I say. I very much question the advisability, too, of placing any confidence on results in candle-power measurements made by any person who has not devoted a great deal of time and attention to this sort of testing. No

test work of which I know is so liable to involve an unconscious personal error of large magnitude.

I wish Mr. Willcox had told us more of why the 80 per cent. limit is taken so commonly for the age limits of lamps and who proposed it. It seems as though it was a suggestion of a couple of years since, adopted at once by every one without question as to its being the proper limit. Of course, we know that the useful life of a lamp is controlled and so determined by its cost, the cost of the power it uses, and the decrease in candle-power per hour it burns. But obviously these are not fixed quantities, and it does not, therefore, appear why, when a 16 candle-power lamp gives only 12·8 candle-power, it is to be thrown away. I do not believe it is right to do so on the circuits of an isolated plant, however good practice it may be in central station work. As the candle-power drops, the total watts drop too, and although not in the same proportion, still it is cheaper to use these old lamps in corridors, in closets, in cellars, etc., than to throw them away.

I wish I could ask Mr. Willcox, too, whether he knows who originated the target diagram as a means of showing what lamps are and how a lot of lamps compare. I think the name is particularly happy, and the diagram (simple as it is) wonderfully expressive. I am very glad that the man who thought of it did not patent the idea; he was a public benefactor. Ever since I came upon it a year or so ago I have used it with a great deal of satisfaction.

One thing more. There has been a notable change in a few years past in the size of the bulbs used with lamps of a given candle-power. A few years back, for example, the 32 candle-power bulbs were about 3½ inches in diameter and 6 inches long. Now we get them no larger than the bulbs of the 16 candle-power lamps used to be. Mr. Willcox tells us that European lamps are made still smaller than American. I wonder what influence the size of the bulb has on the life and maintained candle-power of an incandescent lamp. Certainly the small bulbs give to the lamps an added artistic merit, but one would like to know he is not paying too high a price for this. I am inclined to believe that small bulbs go with short life and rapid decline in candle-power.

PROF. W. M. STINE:—One of the most significant statements in Lieutenant Willcox's paper is the following: "It has taken years to bring home the real considerations (of the incandescent lamp) to electric lighting companies. These considerations are that a lamp is primarily designed and used to give light—that lighting companies are in the business of making and selling light, not power—and that the lamp is the chief essential of the lighting system."

It may be taken as a general law in the development of engineering practice in all lines that, at first, attention is mainly centered on mere accomplishment; and then, as the principles involved come to be better understood, they are examined in detail for efficiency of operation. However, in the case of the incandescent lamp it seems singular that such a statement as the author makes here should obtain; yet those who have had to do with the subject of incandescent lighting have repeatedly experienced its truth. In this line of operation the same remarks apply with equal force to switchboard and metering apparatus. It has required years of vigorous education of those operating and installing plants to recognize that a finely finished case may cover an exceedingly crude and ill-made instrument, and that the readings of instruments are valueless when the calibration of the scale is not known. Again, the same thing has occurred in the matter of suitable transformers, of the proper quality of carbons for arc lighting, and in varying degrees to almost every detail of installation for lighting and power.

The present paper is essentially educational in tone and argues that the leading manufacturers of lamps yet find that the most essential thing in a lighting installation—the final translating device—is so greatly overlooked. It is in this spirit, then, that the present discussion of the paper is presented.

The processes of manufacture have been reduced to such accuracy of details and to standard conditions, and cellulose filaments are made with sufficient uniformity in resistance and size, that further treatment on such account is unnecessary, in so far as treatment is needed for correction of imper-

fections in density, cross-section and length. It is important to note that flashing is no longer required for mechanical corrections. This clears the way, then, for understanding the necessity for plating all filaments with a layer of carbon deposited from a hydrocarbon vapor; the plating being needed for imparting certain necessary properties to the filament to insure proper economy in operation and length of life.

The surface of the cellulose filament, after carbonization, is somewhat rough and has a dull black appearance and its carbon is in an amorphous condition, and its properties in this state which affect the translation of electrical energy into heat and light energy must be examined.

The property by means of which heated carbon radiates its heat and light is termed emissivity, and for conciseness we may think of the emissivity being defined by the quantity of light and heat given off from the square millimeter of surface in the unit of time. The emissivity of a carbon filament is largely determined by the nature of the superficial layer, the interior of the filament having little influence on the emissivity. In general, filaments with a dull black surface show high emissivity for both light and heat.

Flashing consists in heating the filament electrically in an atmosphere of gasoline vapor; the heating of the filament decomposes the vapor in contact with its surface, and the carbon is deposited as a plating on the filament. The character of this plating is influenced by the density of the hydrocarbon atmosphere, and both the temperature at which it is deposited and the rate of deposition. The lower the density of the hydrocarbon vapor, the slower will be the rate of plating, and as a result the deposited surface will be both smooth and hard. And further, at a high temperature the carbon plating will become gray in color and very hard—graphitic, in short. The best conditions for plating are thus: a high temperature of the filament, and low density of the hydrocarbon atmosphere which will insure that the plating shall progress slowly. It may be considered that the plating under these conditions consists of hard, graphitic carbon.

Weber,* examining filaments which were untreated, or had a dull black surface, and comparing them with treated ones having bright gray and metallic-appearing surfaces, found that the emissivity of the two classes averaged the relation of 100 to 75·5. It is known that the emissivity of lampblack and graphite stands in the relation of 100 to 75; and the confirmation is clear that the gray coating of the filament is graphitic. The result, then, of flashing a filament under proper conditions is that its emitting surface becomes graphitic, which at a given temperature causes it to give out less light and heat; and because it thus loses less energy in a unit of time, it will require less energy to raise it to a given temperature and maintain it in that condition.

This treatment, however, does not result in any gain in the proportion of the light radiated in the total radiation; for both dull black filaments and those coated with graphite show the same proportions of light and heat radiations for the various temperatures at which the incandescent lamp is operated; or, in other words, the watts to the candle-power at any temperature will be the same for each class of filaments. For illustration, two filaments may be considered;† the one, *A*, having a dull black, or untreated surface, and the other, *B*, a treated, graphitic surface. The filament *A*, before flashing at a temperature T_1, gave 21 candles with 84 watts expended; and when flashed and again brought to this temperature T_1, it gave 15 candles with 60 watts. For a higher temperature T_2 the results were as given in the table:

Filaments.		Candles.	Watts.	Watts to the Candle.
Black	at temperature T_1	21	84	4
Gray	at temperature T_1	15	60	4
Black	at temperature T_2	28	90	3·22
Gray	at temperature T_2	21	68	3·24

The failure of an incandescent lamp to maintain its candle-power, especially marked after several hours' burning, is

* *Physical Review*, 1894, page 116.

† "The Incandescent Lamp," G. S. Ram, page 63.

very largely due to a change in the emissivity of its surface. Repeated heating of the filament may be considered to bring about gradual annealing of the graphitic layer with a tendency toward the condition of amorphous carbon. This would naturally increase the emissivity, a result which is known to occur. In one case Ram found the emissivity to have increased about 25 per cent.* The immediate effect of increasing the emissivity is that the temperature will be lowered; for if the amount of heat generated in the filament, or the watts supplied to it remained constant, while the filament cooled more rapidly, the temperature would fall. At the lowered temperature the proportion of light radiated to the total energy is greatly decreased; and though the total light and heat radiated at the lower temperature would be the same as before, the proportion of the light to the heat radiated is so much lessened that the lamp drops in candle-power and increases in the watts expended to the candle-power.

The two great factors governing the selection of incandescent lamps are: (1) the watts to the candle, and (2) the maintenance of the initial candle-power. The requirement to meet the first is low emissivity which will cause a filament to be operated at a high temperature to produce the initial candle-power; for at a high temperature (corresponding to bright, white light) the proportion of the light to the heat radiated is greatly increased, which amounts to the statement that a high efficiency is obtained. It has already been seen that when the flashing is properly done the filament will meet this requirement.

The failure to maintain the initial candle-power is usually explained by the evaporation of carbon, which decreases the cross-section of the filament and increases its resistance. While this does occur to some extent, it is only an inconsiderable factor in the case of well-made lamps. The droop in the candle-power curve is frequently already pronounced before the bulb becomes especially discolored and the filament can have lost much by evaporation. The main cause

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* Reference cited, page 64.

at work is the increase in the emissivity of the surface; the graphitic plating slowly becomes amorphous carbon, the appearance of the filament in the meantime changing from a polished gray surface to a duller and rather black one, all brought about by a species of annealing.

When purchasing lamps, preference ought to be given to the filaments which have a bright gray and well-polished appearance, for such filaments will prove both efficient and long-lived when properly operated. The appearance alone is not a sufficient guide; the graphitic layer should have been deposited very slowly in a hydrocarbon atmosphere of very low density that the plating may have taken place at a reasonably high temperature. If the plating is done at the proper temperature and not too rapidly deposited, the annealing of the surface layer will take place more gradually, leading to better maintenance of the candle-power. It is generally understood that a lamp showing excellent maintenance of the candle-power is not one to show high efficiency, and that a lamp of high initial efficiency will soon lose in candle-power. It has now been shown that this is practically a question of the emissivity of the surface layer. In the lamp for maintained candle-power the flashing must be done slowly in fact, but at a lower temperature than is used for higher initial efficiency.

The most radical improvement in the incandescent lamp must result from a combination of these two features in one filament, and doubtless the manufacturers will presently learn to deposit a graphitic coating which will not readily anneal and increase in emissivity.

Mr. F. W. Willcox:—In Professor Rowland's discussion of my paper he alludes to the lamps made some years ago with low vacuum through insertion of inert gas. Professor Rowland describes these lamps as some of the best in the market. In this respect he is in error, as these lamps, far from being the best in the market, were very unsatisfactory, so much so that the manufacturing of them was discontinued.

In view of this fact there is no occasion for the doubt he expresses as to the question whether a spark coil test may not work a hardship on real good lamps.

The limits referred to by Professor Rowland as given by me should be understood as average limits, and the limits mentioned in his requirements should be individual limits.

His comments on different results obtained from tests by various stations are in general true. It must be observed, however, that it is not necessary that tests made on different plants should agree. Any one station making a test on lamps simply wishes to find out the comparative differences between makes when tested on their circuits for candle-power performance. All the lamps on the test would be burned together and subject to the same fluctuations of voltage, and, therefore, the difference should indicate the approximate percentage of superiority and inferiority. A proper laboratory test to determine absolute differences between lamps should only be made, of course, under absolutely perfect regulation of voltage.

The 80 per cent. age limit of lamps was adopted as an agreed limit by the leading illuminating companies of the country.

The actual economy of a lamp starting at 3·1 watts per candle will change through a 20 per cent. loss of candle-power to 3·75 watts per candle, so it is evident that this limit is none too high considering the ratio of light given to power expended. It does not follow that it is necessarily cheaper to use old 16 candle-power lamps in corridors, cellars, etc., than to throw them away, as the cost of light can be reduced in many cases by using new 6 or 8 candle-power lamps in such locations, consuming less than one-half of the total wattage taken with the old 16 candle-power lamps.

There is and always has been too much of a tendency to attempt to use old lamps. The incandescent lamp has a certain period of useful service, beyond which it is useless. It is false economy to attempt to use it beyond this point. The cost of current during the period of lamp service is eight to ten times the value of a lamp, and the lamp, therefore, soon eats up its own value in current a number of times.

The tendency to hold on to old lamps and use them is

responsible more than anything else to day for any poor quality that may exist in incandescent lighting service. Old incandescent lamps should be considered in the same category as old tomato cans or any other old waste truck to be broken up and discarded, and not continued in service because they continue to burn.

Regarding the target diagram, the idea of this was suggested by the writer to Mr. W. S. Howell, Secretary of the Association of Edison Illuminating Companies, and was first worked out and used by him in connection with the lamp tests of the Association of Edison Illuminating Companies.

The influence of the size of bulb on the life and maintained candle-power of incandescent lamps is an interesting topic.

There would be a definite difference in candle-power and life performance were the bulbs of lamps proportioned in size to the candle-power. This is not the case, however, the 24 candle-power bulb for instance being the same size as the 16 candle-power. Better results in candle-power performance and freedom from blackening in same candle-power lamps are always possible with larger bulbs. This is shown in European type of lamp, which is made in a much smaller bulb than the American. This limits the candle-power performance of results to be given by these lamps, and even with everything else equal will always give inferior results than the larger of the American type of lamp.

I am particularly interested in Professor Stine's comments on the paper, especially as he seems to have struck the keynote of the discussion in regard to the use of lamps, namely, the difficulty of getting lighting companies to appreciate the real consideration of incandescent lamps, their light-giving qualities. He correctly analyzes the cause of this. It is surprising, however, how much ignorance and indifference still exist among the numerous central stations throughout the country, and particularly abroad on the Continent of Europe, where the electric lighting suffers from the total disregard of this feature of incandescent

lamps. Professor Stine speaks quite positively as to the cause of loss of candle-power in incandescent lamps, and it would be interesting to know on what he bases his theory. There are many rather novel and surprising things in this part of the discussion referring to the treatment of the filament and annealing process, and considerable experimental proof should be given before they could be accepted as final.

Mining and Metallurgical Section.

Stated Meeting, April 11, 1900.

RAILWAY BEARINGS: AN INVESTIGATION OF CAUSES OF HOT BOXES IN RAILWAY SERVICE, AND METHODS FOR THEIR PREVENTION.*

By Robert Job,
Chemist to the Philadelphia & Reading Railway Company, Reading, Pa.

I take pleasure in presenting herewith results of an investigation to determine causes of hot boxes in railway service due to defects in the bearings themselves, and methods for their prevention.

It is a fact, well known to those who have made a study of bearing metals, that physical condition and structure exert a marked influence upon the efficiency of the metal in service. Formerly great stress was laid upon the general chemical composition of the alloy, and comparatively little attention was paid to the effects of the different conditions of foundry practice, or to the relation between structure and efficiency. The natural results followed, and "hot boxes" became prevalent in railway practice, especially so when weights and speeds became materially increased. Attention was thus directed to the production of cool-running and durable bearings.

As a result of carefully-conducted service tests, the old

*A partial report on this subject appeared in the impression of the *American Engineer and Railway Journal* for February, 1900.

copper-tin alloy of seven to one was found to be inferior as a bearing metal, and the copper-tin-lead composition was gradually introduced, at first combined with phosphorus, and later with this element present in very small proportions, if at all, and then used only as a deoxidizing agent. Also, the efficiency in antifrictional qualities of a copper-tin-lead composition, other things being equal, was shown by Dr. Dudley to increase with the proportion of lead which was present, the amount being limited, owing to the necessity of maintaining a strength sufficient to support the load, and also a fairly high melting point in order to prevent fusion and running from the box if heating resulted. In the best practice not more than 15 per cent. was present, owing partly to the above reasons, and partly to the inability at that time to satisfactorily combine a larger proportion.

During the past few years greatly increased attention has been paid to the microscopic study of the metals, and the importance of this method of investigation is becoming clearly recognized in view of the results which are being obtained through its use. In the course of an investigation to determine the alloy most efficient for general railway use, we found it desirable to follow up this structure of bearing metals in order to note the influence of this as well as that of chemical composition upon durability in service.

To secure information, a large number of bearings which had run hot and had been removed from cars of different railroads while passing over the Philadelphia & Reading Railway were taken for test. Fractures were made to show the general physical character of the composition, sections for microscopic examination were removed, polished, etched, magnified as far as necessary to show the structure to best advantage, and photographed. Analyses were also carried on at the same time, especially in cases where marked segregation of the metal was found to exist, in order to determine whether this result was due simply to an attempt at the foundry to form an alloy in proportions which were physically impracticable, or whether it was an effect of improper foundry manipulation. The marked crystallization which was often found in these bearings was also investi-

gated in a similar manner. Also, in the majority of cases, test sections were cut from the bearings, and the tensile strength and elongation determined in order to find out whether in a given composition proper foundry practice would not be ensured by placing a limit upon the strength and ductility of the alloy.

Side by side with these tests a considerable number of alloys have been prepared in the foundry to check the accuracy of the deductions and to secure information as to the conditions of foundry practice necessary to give the greatest strength and ductility to the given composition, the objects throughout the investigation being, first, to determine the sources of excessive friction inherent in bearings prepared under widely differing conditions of foundry practice, then to find out by experimentation the practice by which such defects were produced, as well as the methods and manipulation necessary to insure the most efficient results, in order to establish in our foundries a thoroughly serviceable standard practice as free as possible from observed defects.

In the composition of the bearings a wide variation was naturally found, among others being the old copper-tin alloy of seven to one, and copper-zinc bearings running as high as 35 per cent. in zinc, an alloy which, by the way, had seldom been discarded owing to heating resulting from defects in the bearings themselves, but which showed evidence of exceedingly rapid wear; phosphor-bronzes were found in moderate amount, while most numerous of all—probably because most used—were the copper-tin-lead compositions, varying in their proportions considerably, but averaging from 10 to 15 per cent. of tin, with from 15 to 5 per cent. of lead, the balance being principally copper. In the majority of cases, however, the mere general composition was found to have caused but small part of the difficulty. The main causes were the following:

(1) Segregation of the metals.

(2) Coarse crystalline structure.

(3) Dross or oxidation products, and an excessive amount of enclosed gas in the metal.

In addition to these the lack of proper lubrication might be mentioned, though our investigation seems to show that a relatively small percentage of the bearings examined had been discarded owing solely to this cause.

Segregation has been found to be due in many cases to an attempt to alloy the metals in improper proportions, this being notably the case in some of the copper-tin-lead compositions in which an excessive proportion of lead had been introduced, with the ordinary practice, resulting in the liquation of a portion of the lead, and often also the separation of a part of the copper into "copper spots," thereby producing surfaces of relatively high heating capacity, and ultimately causing "hot boxes." *Fig. 3* represents a photomicrograph of a copper-tin-lead composition which had segregated owing to pouring too rapidly when at a high temperature. In this case a portion of the lead had separated out, and also a slight crystallization is seen, owing to the presence of a slight excess of silicon in the metal. *Fig. 12* represents a bearing which had been badly segregated owing to rapid pouring, and had run hot in service. The composition was as follows: Copper, 74·67; tin, 15·27; lead, 10·27. *Fig. 1* is a photograph showing upon one side the fracture of a badly segregated bearing with "copper spots," and upon the other that of a well-mixed and homogeneous composition taken at random from our daily output, the segregation in the one case being due partly to the presence of an excessive amount of lead in the brass, but mainly to rapid pouring at high temperature.

To a certain extent these segregations may be prevented even in a wrongly proportioned alloy simply by rapid chilling of the metal immediately after pouring, as for instance by the use of a cold iron mould. Such practice is, however, at the expense of the ductility of the metal, and causes a marked increase in brittleness with consequent rapid wear in service. High heating, combined with rapid pouring and feeding, is, as mentioned, a very frequent cause of segregation, since under such conditions the metal in the mould remains for a considerable time in a molten condition, and by chilling gradually is given the greatest possible chance

to solidify in definite natural alloys, throwing out whatever excess of metal may be present beyond these proportions, and thus resulting in segregation.

In actual service the effect of these segregations is readily understood, for it is evident that instead of an alloy of uniform hardness and heating capacity there is a mixture, some portions of which are relatively very hard, and others very soft, and this difference, combined with that occasioned by the varying heating capacity of the different portions, naturally localizes friction, and ultimately results in excessive heating. In a homogeneous alloy no such conditions exist, and although, as is true of some compositions, some of the metals may be present, at least in part, in mere mechanical mixture, and not as a definite alloy, yet the particles may be made so small that the friction throughout the bearing is practically uniform, and undue local heating is not liable to occur excepting through some outside agency. A fine-grained structure is obtained in these metals by means of comparatively slow pouring, the object being to have the metal in the mould remain in a fluid condition as short a time as possible, thus preventing any tendency towards segregation or settling out. Pouring at too slow a rate, on the other hand, tends to form "shot" in the bearing through the freezing of the metal before it has flowed completely into the mould. The proper rate of pouring can, however, be easily determined by careful experiment, and must be watched very closely in order to secure uniformly good results.

The coarsely crystalline structure which was often seen in these defective bearings was in some cases found to be due to the composition of the alloy, antimony especially tending in this direction. In many cases, however, it has been traced to the foundry practice, often being due to rapid pouring at high temperature. In *Fig. 10* we represent the condition of a crystalline bearing which had run hot in service. Crystallization was also often caused, as will be shown later on, by the presence of an excess of various materials which were originally added as deoxidizing agents.

The effects of this coarse crystallization upon the dura-

bility of the bearing are twofold. In the first place, increased local friction results in the same manner as in the case of segregated bearings, owing to the varying degrees of hardness and heating capacity of the constituents, and secondly, the ductility of the metal and the tensile strength are materially decreased. As the rapidity of wear with a given tensile strength has been proved by different experimenters to increase with brittleness, it becomes evident that the durability of one of these crystallized bearings in service is bound to be defective owing to an excessive rate of wear, even though the heating which would naturally result should not occur.

Fig. 9 represents a segregated copper-tin alloy containing about 80 per cent. of copper and about 0·1 per cent. of phosphorus, showing the crystalline structure of such composition, and it may be mentioned in passing that the old copper-tin alloy of seven to one, having a somewhat similar structure, and formerly much used as a railway bearing metal, is a notoriously rapidly heating composition, and is not often found to-day used for this purpose. *Fig. 2* is a photograph of one of these badly crystallized brasses together with one showing a homogeneous and fine-grained structure.

Another very common source of difficulty found in defective bearings was the presence of particles of dross or oxidized metal mechanically enclosed, and also of large amounts of occluded gas in the metal. In the former case a hard, cutting surface was presented to the journal, causing increased friction, and hence heating. The presence of occluded gas in excess also tended in the same direction by reducing the actual bearing surface of the brass, and thus materially increasing the pressure. Such metal was naturally found to be very brittle, and to have worn rapidly in service. In the foundry practice the presence of this enclosed matter is as injurious as in the bearings themselves, tending to cause sluggish pouring, unless the metal is heated to a very high temperature, in which case crystallization and segregation—as shown above—are liable to result unless the speed of pouring is very carefully regulated.

Lack of fluidity also tends to prevent the formation of sharp, clean castings.

Fig. 6 represents dross mechanically enclosed in a copper-tin-lead composition, and *Figs. 7* and *8* show this appearance of the metal when containing an excess of occluded gas, and show clearly the loss of bearing surface which may result from such porous condition.

In ordinary practice the foundrymen, if left to their own devices, avoid sluggishness of the metal by simple heating until sufficient "life" has been given. If the metal does not contain any appreciable amount of dissolved gases or oxidation products, such practice is perfectly correct. Unfortunately, however, the bearing metals in general retain obstinately a considerable amount of gas which is bound to cause sluggishness unless removed, and failure to effect this renders high heating necessary to give proper fluidity, and as in most foundries the piecework system is in vogue, the main object of the men is to empty the metal into the flasks in the shortest possible time. Thus we have two elements combined, high heating and rapid pouring, which, as has been explained, are almost certain forerunners of hot boxes, owing to the segregation which generally results.

Sluggishness can be entirely prevented with a minimum amount of heat by simply removing these dissolved gases and oxidation products from the metal, and this can be effected by the use of any good deoxidizing material. It is, for instance, a matter of common observation that when a small amount of phosphorus is introduced into a pot of molten metal a marked increase in fluidity results, and upon microscopic examination of castings made before and after the addition, the structure of the latter will be found much the denser, and, as a result of this, both strength and ductility will be found to have increased considerably. Phosphor-bronze is, perhaps, the best-known metal of this class, and is noted for its fluidity in the foundry and density of structure owing to thorough deoxidation of the metal.

The wearing properties and strength of such metal have been found by different observers to be much greater than those of a metal of the same approximate composition but

not deoxidized. Unfortunately, however, in the phosphor-bronzes the attempt has been made to effect what may be termed "cumulative deoxidation," or, in other words, to store up deoxidizing material in the metal sufficient to remove oxidation products which may form upon subsequent remeltings. This effect, however, does not seem to result to appreciable extent, but, instead, a network of crystalline salts of the various metals is formed, and upon repeated remeltings this proportion of oxidation products gradually increases until finally the condition of the metal as a bearing is worse than if the deoxidation had never been attempted. *Fig. 4* represents the structure of a bearing which contained an excess of phosphorus, and shows the appearance of structures which is often found, and renders evident why such excess should be carefully avoided in the most efficient bearing metal. Phosphorus has been mentioned in this connection simply as an exponent of a general class, but the same may be said of any other substance which combines with the bases present to form salts. Excess of silicon, for instance, results in the crystallization shown in *Figs. 3* and *5*.

Turning now to what may be termed basic deoxidizers, or metals like zinc or sodium, which combine readily under the conditions of the foundry with whatever oxidation products may be present in the metal. The action of zinc as an aid in producing sound castings has been long known, and in 1892 Dr. Dudley pointed out that not more than between 1 and 2 per cent. should be added to the molten metal, the reason of this being that sufficient oxygen and oxidation products are usually present to combine with the greatest part of that quantity, forming oxide of zinc, which rises to the surface or passes off as a fume, leaving but little of the metal itself to act as a weakener. The effect of metallic sodium in small amount is similar to that of zinc, excepting that the action is much more energetic, and hence but a very small quantity is required to effect the change. Excess of these bases appears not to detract in any way from the antifrictional qualities of the bearing; they do, however, act to a marked extent as weakeners,

decreasing both tensile strength or ability to carry loads, and elongation or wearing quality.

In any large railway foundry considerable quantities of bearings discarded through one cause or another from cars of foreign roads are received in the scrap heap. Such bearings may contain a good deal of "yellow brass," that is, metal containing a considerable proportion of zinc. If much of such brass is added to the pot, a considerable proportion of zinc is introduced, and comparatively rapid wearing in service is certain to result. The best practice in such cases is, perhaps, to set aside such yellow bearings, and to add but one of them to a pot of metal, or just enough to correspond to the 1 to 2 per cent. of zinc desired, omitting then the addition of spelter entirely. By this means the good results of the deoxidation by means of the zinc may be obtained without retaining sufficient excess to produce brittleness. Zinc of itself does not, however, effect complete deoxidation, as may be shown by observing the increased fluidity in a pot of metal upon adding a small amount of silicon or phosphorus after deoxidation with the zinc, and noting the oxidation products which subsequently rise to the surface. The density of the metal also will be found, upon test, to have increased after the addition. In our own practice we prefer the use of silicon in very small proportion after the addition of zinc in the form of spelter, or as yellow brass. By this means a very strong close-grained and ductile metal is obtained at a minimum cost. We find it necessary to regulate the amount of silicon very carefully in order to avoid the partial crystallization which, as has been shown, would otherwise result. It is easy, however, to determine the amount needed by experiment, adding a definite quantity of silicon to the melted metal after partial deoxidation with about 1 per cent. of zinc, stirring thoroughly, and pouring at once. A section is cut from a casting, and polished, etched and magnified. If an excess of silicon is present the crystalline appearance will be seen, as in *Figs. 3* and *5*. If this is the case, the amount of silicon should be reduced in the next batch, and a section again examined, this being continued until but a bare trace

of silicon is found in excess, thus ensuring almost entire absence of crystallization due to this cause. In our practice we have found that the amount of the deoxidizer required in the different lots of scrap is fairly uniform, and we therefore merely add to each pot the amount found necessary upon an average, checking up the quality by taking bearings at random from the daily output, a practice which we consider indispensable in maintaining efficiency among the workmen. Arsenic is sometimes used to effect deoxidation, but gives no better results than other deoxidizers, and should not be tolerated in the foundry on account of its poisonous properties.

Turning now to the influence of the above-mentioned defects upon the tensile strength and elongation of the bearings examined. Dross or oxidation products are simply elements of weakness, and thus reduce both tensile strength and elongation. Coarse crystallization and segregation both tend in the same direction. With the former, the faces of the crystals form the surfaces of least resistance, and thus facilitate fracture and lessen ductility, while in the segregated bearing the different portions of the metal vary in tensile strength and elongation, so that the section tears apart under a comparatively low stress. Excess of deoxidizers also acts in a similar manner, and the result is especially marked in case of excess of zinc or of sodium, ensuring comparatively rapid wear in service. A test section taken from the bearing represented by *Fig. 4* showed a tensile strength of only 10,500 pounds per square inch, with an elongation of only 4 per cent. in a 2-inch section. A bearing of the same composition if properly prepared in the foundry and free from crystallization would have a tensile strength of about 25,000 pounds per square inch, and an elongation of about 13 per cent. when the test sections were taken from the bearing in a similar manner.

In the porous brasses we naturally found the same lack of strength and ductility owing to the deficiency in the amount of metal present in a given section. For example, the bearing represented by *Fig. 7* showed a tensile strength of 15,000 pounds per square inch, with an elongation of only

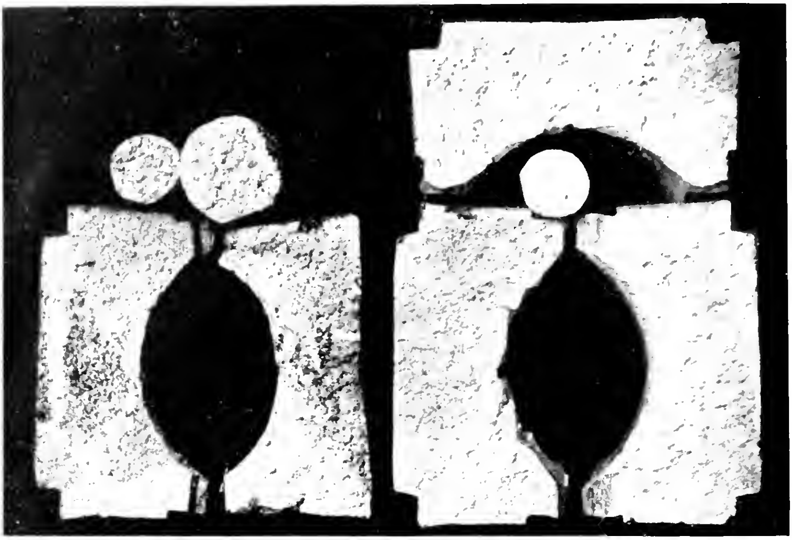

Fig. 1.

Fig. 2.

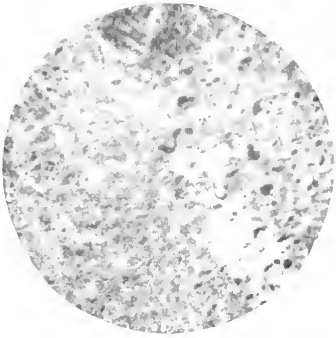

Fig. 3.

Fig. 4.

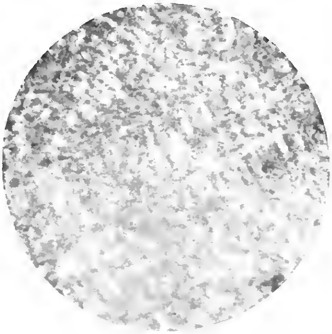

Fig. 5.

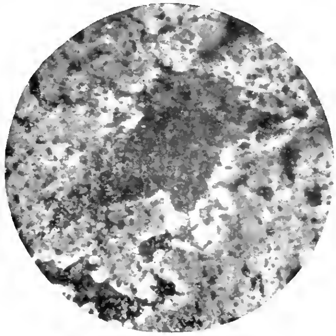

Fig. 6.

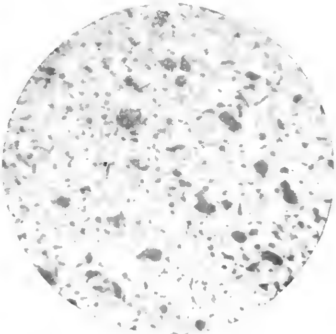

Fig. 7.

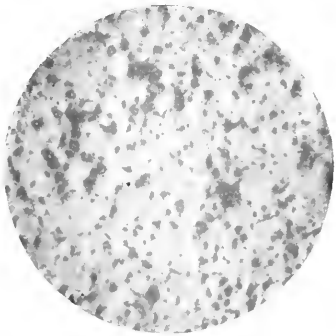

Fig. 8.

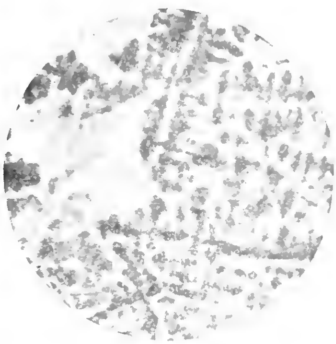

Fig. 9.

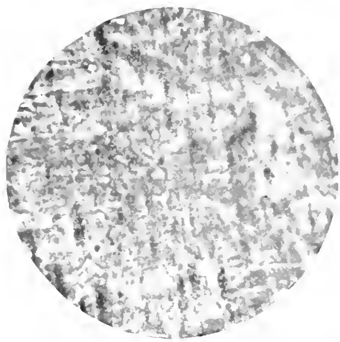

Fig. 10.

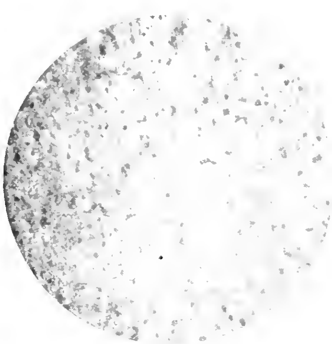

Fig. 11.

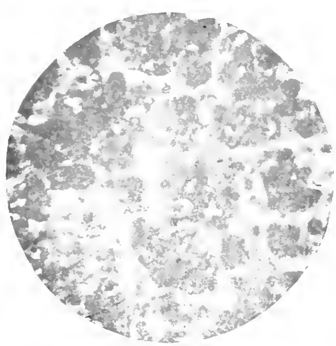

Fig. 12.

6 per cent. *Fig. 8* showed a tensile strength of 18,700 pounds per square inch, with 7 per cent. elongation. Thus we see that the influence of the various defects is clearly shown when metal of a known composition is subjected to tensile tests, and it becomes possible to hold the foundry up to a high grade of excellence by this comparatively simple means with analytical and microscopic work as a basis.

Objection may, perhaps, be made that it appears rather arbitrary to place limits upon tensile strength and elongation in bearings, and that, after all, in practical service it is merely necessary to have, with a proper composition, a fairly strong homogeneous material to obtain good results. In reply, we will merely state that as a result of very carefully conducted service tests made by placing bearings of practically the same composition, but differing widely in both tensile strength and elongation, upon opposite ends of the same axles, we have invariably found that increase of strength and ductility meant an increased life to the bearings in service and a lessening of wear, our results in this respect being in accordance with the deductions given by Dr. Dudley in 1892 before the Franklin Institute. As an instance of difference in efficiency due to these causes, we may cite a service test in which eight bearings each, of two copper-tin-lead compositions, were placed under tenders of fast passenger locomotives, one bearing of each kind being placed upon an end of each axle. All the bearings were of practically the same composition, but the one set showed a tensile strength of about 16,500 pounds per square inch, with an elongation of about 6 per cent., while the other had a strength of about 24,000 pounds per square inch, with an elongation of about 13 per cent. This marked difference was due simply to the fact that in the one case the metal was porous, about as shown in *Fig. 7*, while the other was thoroughly deoxidized, and was close-grained and homogeneous, similar in structure to *Fig. 11.* From time to time these bearings were removed and weighed, and the end wear measured. As a final result, it was found that the more brittle set had worn 35 per cent. more rapidly than the others. The results of similar tests, also, have been in

line with the above. Therefore it becomes evident that increased ductility and strength in the bearing of given composition means, as stated, an increased life for the bearings in service, and, as relatively high ductility necessitates also freedom from the defects which we have mentioned, it is evident that the chances of cool running are proportionately greater. These qualities are therefore not merely of theoretical interest, but have an intensely practical value, and have a marked influence upon the success and economy of railway service.

Regarding the preparation of the sections for microscopic study, we have found it desirable to cut them from the center of the bearing, filing and polishing after the usual methods, and finally etching with an approximately decinormal solution of iodine in potassium iodide, the time of etching being usually about one minute. This etching gives very satisfactory results in many cases, though in some etching with dilute chromic or nitric acid has shown the structure to better advantage. In ordinary work we have found that magnification to about thirty diameters is sufficient.

DESCRIPTION OF PLATES.

FIG. 1.—Fine-grained and homogeneous. P. & R. Ry. standard. Crystallized by defective foundry practice (copper-tin-lead bearings).

FIG. 2.—Segregations. Fine-grained, homogeneous bearing. P. & R. Ry. standard (copper-tin-lead bearings).

FIG. 3.—Segregation; also silicide crystallization (copper-tin-lead bearing).

FIG. 4.—Crystallization due to phosphides (copper-tin-lead bearing).

FIG. 5.—Silicide crystallization (copper-tin-lead bearing).

FIG. 6.—Enclosed dross (copper-tin-lead bearing).

FIG. 7.—Enclosed gas (copper-tin-lead bearing).

FIG. 8.—Enclosed gas (copper-tin-lead bearing).

FIG. 9.—Segregation; also phosphorus crystallization (copper, 80 per cent.; tin, 19·97 per cent.; phosphorus, 17 per cent.).

FIG. 10.—Crystallization (copper-tin-lead bearing).

FIG. 11.—Close-grained and homogeneous (copper-tin-lead bearing).

FIG. 12.—Segregation due to rapid pouring (copper-tin-lead bearing).

THE FRANKLIN INSTITUTE.

Stated Meeting, Wednesday, April 18, 1900.

RECENT PROGRESS IN THE ALUMINIUM INDUSTRY.

BY PROF. JOSEPH W. RICHARDS,
Lehigh University, Member of the Institute.

Professor Richards spoke in substance as follows:

It is not yet seventy-five years since aluminium was first isolated as a metallic powder, and not yet fifty years since it made its appearance as a true solid metal, while until fifteen years ago its price was counted in dollars per pound, and it was used only for articles of luxury or for purposes where lightness was a desideratum and expense was not considered. From 1884 to 1891 several new processes of production followed each other, reducing the price nearly 50 per cent. each year and causing the output of metal to increase nearly 100 per cent. each year, until with the present decade aluminium became a metal of every-day life, for it began to compete with such ordinary metals as German-silver, britannia, pewter, bronze, copper and even brass. To-day sees this new metal firmly established among the every-day metals, known to and used by the general public, and destined to ever-increasing usefulness until its only rival will be iron and steel.

My further remarks will concern only *recent* advances; and in the line of pure metallurgy, that is, reduction and refining, there is little to chronicle. The process of reduction has certainly been somewhat improved in details, but in principle it is the same as the Hall process of ten years ago. The operators of the process are naturally averse to publishing the details of their operations, and the outside public is vouchsafed information only upon the properties and utilization of the metal. About all there is to be said is that during the last few years all the items of expense of the process have been gradually notched down—bauxite is

being mined and prepared better and more cheaply; its conversion into alumina is probably improved; electrolytic carbons are being made cheaper and more durable; electric power is being obtained more cheaply, and, finally, the doubling and doubling again of the size of the works has reduced correspondingly the cost of superintendence and office expenses. These, and probably several other items of saving, have altogether reduced the cost price of aluminium to probably about 20 cents per pound, while its selling price is slightly over 30 cents in the United States and 25 cents abroad.

I could wish to be free to give more information on these metallurgical details, but since that is denied, I will pass on to the various uses of aluminium which have recently appeared.

Here is a small box containing a dozen aluminium thimbles, which was sold in the largest store in this city, this week, for 5 cents. This furnishes me a good text to talk about the displacement of other common metals by aluminium. These dozen thimbles weigh less than $\frac{1}{2}$ an ounce, and the aluminium in them cost the manufacturer just 1 cent. If he had made them of common brass, they would have weighed $1\frac{1}{2}$ ounces, and the metal in them have cost $1\frac{3}{4}$ cents, which is an increased cost of metal of 75 per cent. Or, stating it another way, to manufacture $1,000 worth (selling price) of thimbles, the manufacturer would have to buy to make them (allowing 25 per cent. for waste clippings) $250 worth of sheet aluminium or $437.50 worth of sheet brass. The general public considers brass as a cheap metal, and such facts as the above are rather startling when first grasped.

Coming to the city in the train to-day, I estimated the amount of brass fittings on one railway car as about 300 pounds. Without exception, they were replaceable by light aluminium alloy, which, fully as strong, would weigh only 100 pounds and cost only two-thirds as much. The difference in cost would probably amount to $20 per car, in favor of aluminium, while the saving in dead-weight hauled would be more than the average weight of one passenger per car.

Such instances as the above could be multiplied *ad libitum*, but these suffice to prove the point, little apprehended by the general public, that for almost every practical purpose aluminium is cheaper than all the common metals excepting zinc, lead and iron. Brass, tin, copper, are of approximately the same specific gravity, and in comparing their costs we usually think only of their relative cost per pound; but aluminium is entirely in another class. It takes only one-third of a pound of aluminium to take the place of one pound of these metals, and the proper basis of comparison here is to compare the price of one-third of a pound of aluminium with that of one pound of brass, etc. The comparison, therefore, stands as follows:

One-third pound of aluminium	$0 11
One " " brass	15
" " " copper	17
" " " tin	30

The next great improvement, after that of the fall in price, has been in the successful manufacture of light, strong alloys. This has been a subject at which metallurgists have worked hard and long, and their labors are bearing fruit in abundance. Pure aluminium has many resemblances to pure copper. Take away the red color of copper, and its softness, malleability, toughness, silky fibrous fracture are almost exactly duplicated by aluminium; but they are both soft, rather weak, metals. Five per cent. of aluminium, silicon or manganese or 30 per cent. of zinc added to copper make famously strong bronze or brass. Similarly, 5 per cent. of copper, nickel or manganese, or 30 per cent. of zinc, added to aluminium, make strong metals as rigid as bronze yet only one-third as heavy. Such light, strong, good casting and machining alloys have an extremely large field of usefulness, and will receive a very large application in the near future. It would be possible for me to consume half of the time at our disposal this evening telling alone of the various strong, light alloys which have approved themselves in very recent years; but, as an illustration, I will mention the alloy made by the Delaware Metal Refinery, of this city, and which is one of the best. It is a hard white

alloy, specific gravity 3·1, melts clean, runs fluid, makes beautifully sharp and perfect castings, turns and machines like the finest brass, polishes well, and, to conclude, is fully as rigid and strong as gun-metal or the best of the ordinary bronzes. I do not enumerate this catalogue of virtues merely from my own knowledge of the alloy, but could substantiate it from the experience of Philadelphia firms who are using it regularly and are quite enthusiastic over its possibilities. This alloy is principally of aluminium and zinc, and sells at the same price per pound as pure aluminium. The field of application of light alloys with such properties to light-running machinery, portable apparatus, vehicles, instruments, etc., is almost immeasurable, and the next few years will see its use very general for such and similar purposes.

The use of aluminium for culinary utensils is extending steadily, as their merits become better known. A brief statement of what they are for this purpose is that they possess all the advantages of copper utensils, with none of their disadvantages. The first aluminium utensils put on the market, ten years ago, were generally too lightly made, and were consequently easily dented and bent out of shape. The manufacturers have learned by experience, and the ware now being sold is fully as durable as the best copper ware. An aluminium kettle in my father's house has been on the stove constantly for seven years, boiling Schuylkill water, and is apparently uninjured and unworn. The inside has a brownish adherent skin of oxide which seems to be continuous and to efficiently protect the metal beneath from further oxidation. It bids fair to become an heirloom in the family. [In reply to a question: "The aluminium goods need only as much attention as ordinary tin ware to keep them bright and clean. Bath-brick dust, such as is used for polishing knives, is as good a scourer as can be used on them."]

There are at present a full dozen firms engaged in manufacturing this culinary ware, and it is now so generally known that it was unnecessary for me to display any here as a novelty. This small "bonbonnière," made by Hill,

Whitney & Co., of Waltham, Mass., and modelled after the famous silver porringer hammered out by Paul Revere, is interesting as to its shape, as well as showing the beautiful finish, inside and out, which can be given aluminium ware.

As a distinct novelty in aluminium goods may be mentioned the beautiful ware being made by the native metal-workers in the bazaars and industrial school at Madras, under the leadership of Mr. Chatterton. These native workmen are probably the most skilful metal-workers in the world, and their work is principally confined to steel arms, silver ornaments and copper and brass utensils. The fact that aluminium sheet blanks can now be purchased cheaper than similar sized blanks of copper or brass has given the opportunity to introduce the working of aluminium. The natives have easily mastered the peculiarities of the new metal, and take most kindly to it. The native Indian troops are largely supplied with aluminium ware, and it is coming into favor in all castes, from the lowest to the highest, on account of its lightness and cleanliness, whilst costing no more than copper or brass utensils.

[There were here shown on the screen a number of photographs of the bazaar workshops and their ware, loaned for the lecture by the *Aluminium World*, of New York. The scenes were most realistic, and, judging from the photographs, the ware is equal in construction and superior in artistic finish to any other aluminium ware made anywhere.]

There are upon this table many small articles and novelties in aluminium, loaned by Mr. Mertz, of your city. It would be useless for me even to attempt to name all the various goods which are now being made of aluminium, in which its lightness and prettiness are much in evidence. The toilet goods and pocket articles are especially in favor, and aluminium combs are being made by tens of thousands, and consuming a generous share of all the aluminium sheet made. An equally large use is for fruit-jar caps, for which aluminium is superseding zinc, although more expensive, because of its harmlessness.

In the artistic branch of *lithographic printing* aluminium is rapidly winning an important place. Nearly two years

ago, speaking in this hall about the progress of aluminium industries in Europe, I spoke of the establishment I had visited at Mainz, which printed altogether from aluminium plates. The process was then quite new, but since that time about thirty firms in the United States alone have taken up the aluminium plate printing, and are using it regularly, while the number in Europe is probably forty or fifty. Here is a trade catalogue printed by the Sackett & Wilhelms Company, of New York, which is probably as fine a specimen of commercial color work as was ever printed, and this firm prints exclusively from aluminium plates. The printing is entirely surface work, and is being generally done on cylinder presses instead of flat-bed machines, the aluminium sheets being bent onto the cylinder, and thus allowing of fast running. This is, indeed, a most promising infant industry, which cannot but grow to large proportions, seeing the advantages of aluminium plates over lithographic stone.

Electric conductors can now be laid more cheaply in aluminium than in copper. This is indeed a startling statement when first heard, for almost every one is wont to consider copper as the metal *par excellence* for conductors. But, pure aluminium has over 60 per cent. the conductivity of pure copper, and is fully as strong and resistant to atmospheric influences. It is therefore only necessary to take an aluminium wire one-fourth as large again in diameter as a copper wire (giving a little over 50 per cent. more section) to get equal conductivity. Such a wire weighs one-half as much as the copper wire it replaces, and costs only two-thirds as much. Long-distance transmission lines and trolley-line feed wires are being put in in aluminium as fast as the makers can supply the metal. Over 500 tons of aluminium were used for this purpose last year, and probably double as much will be used this year. As 500 tons supplants 1,000 tons of copper, it will not be long before the copper industry will begin to feel the competition of aluminium, but will probably be unable to meet it. This one use of aluminium promises in the near future to consume its thousands of tons a year. What a contrast to the

industry fifteen years ago, when two and one-half tons of aluminium was the output of the whole world in one year!

The samples of aluminium cables before you were kindly sent by the Pittsburgh Reduction Company, which has been foremost in developing this use of aluminium.

It is now necessary for me to rapidly bring my remarks to a close, and to leave unnoticed many interesting items which might be mentioned did time permit. I will close by referring to *powdered* aluminium and the many applications it is receiving. Aluminium can be rolled out to $\frac{1}{2000}$ of an inch in thickness, and then beaten out to $\frac{1}{40000}$ or even $\frac{1}{70000}$ of an inch. As thin sheet it has found some application in place of cardboard, for business cards, etc., but as leaf it has entirely superseded silver-leaf in decorating. This leaf can, moreover, be ground to powder, and in this condition is used by printers for silvery printing, and as a paint. For the latter use it is simply mixed with a varnish, like ordinary bronzing powders, and has already proven its beauty and utility on Uncle Sam's letter-boxes. Every one here has had the opportunity of seeing this use and judging for himself of its practicability. It is to be hoped that the Public Buildings Commission of your city will not overlook this material when considering the painting or refreshing of the metal work on the City Hall tower. It is not likely that a more suitable, durable or beautiful covering can be obtained than this would give, whilst the cost would certainly be moderate.

The powdered aluminium has recently received an extremely interesting metallurgical application, in the reduction of refractory metallic oxides to the metallic state. Over forty years ago Tissier proved that aluminium energetically reduces some metallic oxides. He mixed the metallic oxide with aluminium powder, heated it in a furnace, and generally succeeded in reducing the oxide to metal and, in some cases, reducing the furnace to ruins. Our esteemed Secretary, Dr. Wahl, with Dr. Greene, made use of the same energetic reducing power of aluminium to produce carbonless metals, by incorporating with the finely-divided metallic oxide the needful quantity of granu-

lated aluminium and reducing the mixture with the aid of heat, in magnesia-lined crucibles, adding a certain quantity of flux to this mixture to facilitate the reduction. They found this process to be specially applicable to the production of carbonless manganese and chromium of a high grade of purity. This is indeed a practicable method of operating the reaction under control.

A further improvement is the method of Goldschmidt, of Essen, Germany, who mixes the metallic oxide with powdered or granulated aluminium and ignites the cold mixture in a cold crucible. The heat thus generated is sufficient to melt the reduced metal and even the resulting alumina, and the danger of explosion is very small. To ignite the mixture, a small hole is scooped in its upper surface, into which is put a mixture of barium peroxide and aluminium powder, which is relatively easy to ignite. A strip of magnesium ribbon or flash-light paper is stuck into this mixture, and lit by a match. The magnesium sets the peroxide mixture off, and this starts the oxide mixture reacting next to it, and the heat thus spreads through the whole mass. In five to ten seconds the entire contents have reacted; the generation of heat is so rapid that the crucible does not become warm outside for some minutes, and is so intense that it is unbearable to the eye, and is probably between 2,500° and 3,000° centigrade. In operating on a large scale, a small amount of the powder is first ignited in the crucible, then more is continually added and the reaction kept up until the crucible is full. Then the melted alumina slag is poured off and the melted metal beneath poured out. The method is applicable to reducing to metal almost all metallic oxides, except those of magnesium, the alkaline earths and earths, and has been applied to the more expensive metals which are ordinarily considered as difficult to reduce, such as manganese, chromium, titanium, tungsten, molybdenum, vanadium, uranium, boron, etc. In some cases the ferro-alloys are made, which are an easier form to introduce the metals into steel, melting easier and diffusing quicker in the steel. At Krupp's works, at Essen, many such alloys are made for use in armor-plate steel, and a

similar class of alloys is being made here in Philadelphia, probably by the same method.

[A mixture of 8 ounces of green chromium oxide with 4 ounces of powdered aluminium was ignited by the lecturer, in the manner described. The heat developed in the crucible was intense, while yet it was cool enough outside to handle, and there was obtained a slag of melted alumina containing buttons of melted metallic chromium. The theoretical amount of the reducing agent in this case was 1 pound of aluminium, in powder or granulated form, to produce 1 pound of chromium. Granulated aluminium costs at present about 40 cents per pound; the powder, $1.25.]

Stated Meeting, April 25, 1899.

ELECTROMAGNETIC MECHANISM, WITH SPECIAL REFERENCE TO TELEGRAPHIC WORK.

By R. A. Fessenden.

INTRODUCTION.

In designing electromagnetic mechanism, we should take as our motto "*cherchez l'erg*," and, having found the way the energy is distributed, we should always keep it in view. It is on these lines that I have written the present paper, and, as we shall see, this method leads to several very simple and useful rules.

As regards the nomenclature used, I have taken the units adopted by the American Institute of Electrical Engineers; *i. e.*,

P = Webers = number of lines of magnetic induction.
G = Gilberts = difference of magnetic potential.
N = Oersteds = magnetic reluctance,
the defining equations being

$$P = \frac{G}{N} \text{ and } G = 4\pi n I,$$

where n is the number of magnetizing turns, and I the current in them, all units being in the absolute electromagnetic system.

Also I have used the terminations -ance or -ion to signify the integral of the quantity and the terminations -ivity or -ibility to signify the intensity of the quantity, or the differential of the quantity with respect to some other quantity, thus:

B = Weberivity = flux per square centimeter.
H = Gilberivity = drop of magnetic potential per centimeter.
ν = Oerstedivity or reluctivity = specific reluctance.
μ = Permeability = reciprocal of reluctivity.
E = Voltage = difference of electrical potential.
F = Voltivity = drop of electric potential per centimeter.

Since, as will be seen, we can treat the subject more easily by dividing the flux into two parts, one due to the ether, which we will call the extrinsic flux, and the other due to the presence of iron or other material, which we will call the intrinsic flux, we have the following definitions:

P_ι = Intrinsic flux.
B_ι Intrinsic flux per square centimeter.
N_ι Intrinsic reluctance.
ν_ι Intrinsic reluctivity.
Q Electrostatic induction = lines of electrostatic flux.
D Electrostatic inductivity = electrostatic flux per square centimeter.

The upright capitals, Q and P, are used to denote quantity of electricity and magnetism, respectively.

It will be noted that I have followed, so far as possible, general usage and the recommendations of the American Institute of Electrical Engineers. It is extremely unfortunate that the theoretical men are perpetually making what they call "practical units," which they for some reason or other suppose are of great benefit to practicians. Thus, when the meter and gram were established, the system taken was the decimal one, and we were cut off finally from the very much preferable duodecimal one, whilst, had the duodecimal one been taken, it might finally have swamped out the decimal system entirely, to our great benefit and gain. Then, when the electrical units were fixed, out of

pity for the practical men the volt was taken as 10^8 absolute units, the ampère as 10^{-1} units, the ohm as 10^9 units, the farad as 10^{-9}, and so on, thus introducing endless confusion and failing in the very object for which all the trouble was made, for at present there is no question but that the volt is too small for practical work and 10^9 units would be better. If the volt, ampère and ohm were taken as the absolute units, the practical units would be the ampère, begohm and begavolt, names just as convenient as ampère, coulomb and farad. It is greatly to be desired that the theoretical men should leave off making any more units which they fancy will be convenient for practical men, and that they will stick to absolute units.

What the practical man wants is this (and I speak from a quite considerable practical experience, and acquaintance with other practical men):

(1) A system in which there are no so-called practical units, but all the units are absolute.

(2) A system of prefixes to denote the power of ten by which the absolute unit is multiplied, as suggested by Kennelly and Houston. Thus, begohm would represent 10^9 units of resistance, and would correspond to our so-called practical unit, the present ohm. Begohm is as easy to say as coulomb.

This system would have the immense advantage that it would not be confusing by necessitating, as the present system does, the introduction of all sorts of coëfficients when we change from one class of work to another. It appears to the writer to be supremely ridiculous to argue in favor of the C. G. S. system because it gets rid of obnoxious coëfficients in changing from, say, gravitational to inertial problems, and then to go and introduce other unnecessary coëfficients, in a much worse form (since it is easier to remember a string of three or four figures than to remember whether a thing is to be multiplied by 10^{-1} or 10^7 or 10^{-15} or 10^9 or 10^8).

Again, no units *can* be practical units, as conditions change so much with time and with the kind of work. A micro-farad is too large for use in telephone work, where

we often specify capacities in terms of tenths or hundredths of microfarads. But in power transmission by the single-phase system we often deal with capacity effects in alternating motors measured by thousands of microfarads. How much better it would have been to have chosen the farad as the absolute unit and let the telephone engineer speak of three hexfarads instead of having first to call it three one-hundredths of a microfarad and then to multiply by some forsaken coëfficient. Similarly the transmission engineer would speak of three trifarads instead of 3,000 microfarads.

(3) One name, with different prefixes and suffixes for all terms connected with each single unit. At present the whole system is in the greatest confusion. As an aid to a comprehension of the existing state of affairs, the following extract from one of the works of a well-known mathematician (though not of itself mathematical in character) is given:

"You are sad," the Knight said in an anxious tone, "let me sing a song to comfort you."

"Is it very long?" Alice asked, for she had had a good deal of poetry that day.

"It's long," said the Knight, "but it's very, very beautiful. Every one that hears me sing it—either it brings the *tears* into their eyes, or else—"

"Or else what?" said Alice, for the Knight made a sudden pause.

"Or else it doesn't, you know. The name of the song is called 'Haddock's Eyes.'"

"Oh, that's the name of the song, is it?" Alice asked, trying to feel interested.

"No, you don't understand," the Knight said, looking a little vexed. "That is what the name is *called*. The name really is 'The Aged, Aged Man.'"

"Then I ought to have said 'That's what the song is called,'" Alice corrected herself.

"No, you oughtn't; that's quite another thing. The song is *called* 'Ways and Means;' but that's only what it's called, you know."

"Well, what *is* the song then?" said Alice, who was by this time completely bewildered.

"I was coming to that," the Knight said. "The song really is 'A Sitting on a Gate,' and the tune's my own invention."

The following dialogue, which can hardly be called imaginary, will now be more readily appreciated:

Electrical Unit Maker.—(Showing one volt cell to man who wants to be an electrical engineer) "This cell gives exactly one unit of Electromotive Force."

Student.—"Why was that name given to the quantity?"

E. U. M.—"I perceive that you misunderstand me; that is not its name, it is what it is called. Its real name is the Volt."

S.—"I beg your pardon; why is it called by the title Electromotive Force?"

E. U. M.—"Because it is not a force and has no immediate connection with motion, that being determined by its space differential."

S.—"Well, if that is what it is—"

E. U. M.—"Permit me to interrupt you. It *isn't*. It really *is* the unit difference of electrical potential. It is defined as the unit difference of electrical potential."

S.—"Ah, now I understand. You explained potential very fully to me yesterday. It is equivalent to electrical energy, then, isn't it?"

E. U. M.—"Not at all, not at all; you misconceive me entirely. It is true that we generally connect the idea of energy with the word potential, but in this case we use it in a special way. It really *is* only *one factor* of energy, and to get the electrical energy you must multiply it by another term, quantity of electricity."

S.—"You will excuse me for a moment, I am a little dazed. As I understand it, then, this unit—"

E. U. M.—"You must be very careful. There are three units. This is not the real fundamental unit. That is only one one hundred millionth of the volt. The volt was chosen this size for your especial convenience."

S.—"O Lord!" (*after a pause*) "then this other term which I see, magnetomotive force, is that also so called because it is not a force and has nothing to do with motion?"

E. U. M.—"Exactly."

S.—"But, from the definition of unit current, it certainly seems as if there must be some tendency for a magnet to move round a wire carrying a current, in the direction of the magnetomotive force."

E. U. M.—"Not at all. That definition was adopted for the sake of making the idea more simple; but, as I have, on several occasions, noticed that professors of electrical engineering have published articles in the technical journals in which, the magnetic lines being represented by vortex rings, they have stated that these rings rotated around the axis of the wire as well as around the axis of the vortex, it may not be so clear as it was originally thought to be."*

S.—"And still I am at fault. Surely this unit magnetic pole—"

E. U. M.—"There *is* no unit pole. True simplicity is obtained by defining things in terms of other things which cannot exist, calling them by names which are as misleading as it is possible for them to be, multiplying them by all sorts of constants, and stirring the whole thing up with a stick. By giving eight or ten names to the same quantity and using the same term with different significations in different connections† still further advantages are obtained. By a judicious extension of these principles and the adoption of still other practical units it is hoped in time to have a system which *no* one can understand."

I jest with tears in my eyes because I have to teach the relations between these units to students. I could get through the work in about one-third of the time if it were not for the inconveniences of the practical units and the names.

How much better it would be to call a certain quantity the voltage, the integral of it the voltance, the intensity of it the voltivity, and the absolute unit itself the volt. By following this system, 110 volts would then be 11 bega-

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* For a recent instance, since the above was written, see *Weidemann's Annalen*, No. 12, 1899.

† As, magnetic moment of a magnet, and of a magnetic shell, the moment of a magnetic shell having to be multiplied by its area to get its moment considered as a magnet.

volts, and there would be no practical units, and all units would be connected by equations without constants. Similarly Gilbertage, Gilbertance, Gilbertivity and Gilbert. As regards symbols, E would stand for voltance, F for voltivity and $\dot{E}$ for time rate of change of voltage.

Is there no hope for a return in 1900 to a rational system of absolute units, names and symbols? This would also give us a chance to get rid of the 4π factor, as suggested by Heavyside.

EQUATIONS OF ENERGY.

The equations expressing electric and magnetic phenomena are four in number; *i. e.*,

$$Q\ P = M\ L^2 / T. \tag{1}$$

$$\kappa\ \mu = T^2 / L^2 \tag{2}$$

$$Q\ \mu = L\ T \tag{3}$$

$$P\ \kappa = M / L \tag{4}$$

where Q = quantity of electricity
P = quantity of magnetism
κ = specific inductive capacity
μ = permeability
M = mass, L = length and T = time.

From these we get the following equations:

$$\frac{Q^2}{\kappa\ L} = \frac{M\ L^2}{T^2} = \text{energy (electric)} \tag{5}$$

$$\frac{P^2}{\mu\ L} = \frac{M\ L^2}{T^2} = \text{energy (magnetic)} \tag{6}$$

$$\frac{Q\ P}{T} = \frac{M\ L^2}{T^2} = \text{energy (electro-magnetic)}. \tag{7}$$

To go more into details, we may separate the L s into L_x L_y and L_z axes, where L_x represents the axis in which the electric force acts, L_y that in which the magnetic force acts, and L_z the axis at right angles to both. We then have:

$$\frac{Q^2}{\kappa} = \frac{M\ L_x\ L_y\ L_z}{T^2} \tag{8}$$

$$\frac{P^2}{\mu} = \frac{M\ L_x\ L_y\ L_z}{T^2} \tag{9}$$

$$\frac{Q\ P}{\kappa^{\frac{1}{2}}\ \mu^{\frac{1}{2}}} = \frac{M\ L_x\ L_y\ L_z}{T^2} \tag{10}$$

$$Q = \frac{M}{T} \tag{11}$$

$$P = L_x\ L_y \tag{12}$$

$$\kappa = \frac{M}{L_x\ L_y\ L_z} \tag{13}$$

$$\mu = \frac{L_x\ L_y\ T^2}{M\ L_z} \tag{14}$$

$$E = L_x^2 / T \tag{15}$$

$$F = L_x / T \tag{16}$$

$$G = M\ L_x / L_z\ T^2 \tag{17}$$

$$H = M / L_x\ T^2 \tag{18}$$

We can now find out how the energy is stored up and the direction of the faces.

Take equation (8).

If we have a condenser with an electric charge on it, we get

$$\frac{Q^2}{2} \div \left(\frac{\kappa \times \text{area}}{\text{dist. between plates}}\right) = \frac{M^2}{T^2} \times \frac{L_x\ L_y\ L_z}{M} \times \frac{L_x}{L_y\ L_z} = \frac{M\ L^2_x}{T_2}$$

Or, if we have a condenser of charge Q and a certain capacity, the energy stored up in the condenser will be equal to half the square of the charge, divided by the capacity, and will be given out by motion along the x axis, *i. e.*, the force is along that axis.*

It will be noted that the capacity of a sphere in vacuo is generally given as its radius, or L_x. It is, however, the area of the sphere divided by $4\ \pi$ times the radius, or $L_y\ L_z \div 4\ \pi\ L_x$.

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* The factor ½ comes in by reason of the fact that there is no voltage to commence with, and it is $\frac{Q}{\kappa}$ when the charging is finished, hence the average value is $Q / 2\ \kappa$.

When the bodies are very far apart the capacity depends very little on the distance, but is proportional to the radius of the bodies. Here there is no force resisting a change of the distance between the bodies, but the force now comes in if we try to change the radius, and hence a soap bubble, as is well known, will tend to expand when charged.

Since electric energy is given by

$$\frac{Q}{2\,\kappa}\,\frac{L_x}{L_y\,L_z} = \frac{M\,L_x^2}{T^2}$$

the energy per cubic centimeter is given by

$$\frac{M\,L_x^2}{T^2} \div L_x\,L_y\,L_z = \frac{M^2}{T^2\,L_y^2\,L_z^2} \times \frac{L_x\,L_y\,L_z}{M} = \left(\frac{Q}{\text{area}}\right)^2 \times \frac{1}{\kappa}.$$

or inserting the proper numerical coëfficient, which, if we use the C. G. S. electrostatic system, is

$$\frac{1}{8\,\pi}$$

* Since unit quantity $= 4\,\pi$ lines and the average value of $\frac{D}{\kappa}$ is $\frac{1}{2}$ the final value.

we get

$$\frac{D^2}{8\,\pi\,\kappa} \tag{19}$$

equals the energy in ergs per cubic centimeter stored up in electrostatic field. Since, if we allow the cube to shorten up along the x axis, the energy will vary as the length along that axis, this same expression gives the force per square centimeter of surface perpendicular to the x axis, or the stress per unit area.

The magnetic formulæ are similar. From equation (9) we get

$$\frac{P^2}{L} \div \left(\frac{\mu \times \text{area}}{\text{dist. between plates}}\right)\frac{L_x^2\,L_y^2}{1} \times \frac{M\,L_2}{L_x\,L_y\,T^2} \times \frac{L_y}{L_x\,L_z} = \frac{M\,L_y^2}{T^2}$$

Energy per cubic centimeter and stress per square centimeter equals

$$\frac{B^2}{8\,\pi\,\mu}$$

We may make various permutations and combinations of these symbols by substituting values taken from equations previously given. Thus,

$$\frac{D^2}{8\,\pi\,\kappa} = \frac{D\,V}{8\,\pi} = \frac{V^2\,\kappa}{8\,\pi}$$

$$\frac{B^2}{8\,\pi\,\mu} = \frac{B\,H}{8\,\pi} = \frac{H^2\,\mu}{8\,\pi}$$

If we have a piece of glass in an electrostatic field the energy per cubic centimeter is, in the space where the glass is, $D^2/8\,\pi\,\kappa$. If the glass be moved 2 centimeters away, the energy in the space formerly occupied by the glass is now $D_1^2/8\,\pi\,\kappa_1$. In the place where the glass now is the energy was formerly $D_2^2/8\,\pi\,\kappa_2$, and is now $D_3^2/8\,\pi\,\kappa$. The total loss of energy in the space where the glass was at first is therefore

$$D^2/8\,\pi\,\kappa - D_1^2/8\,\pi\,\kappa_1$$

and the gain at the second place is

$$D_3^2/8\,\pi\,\kappa - D_2^2/8\,\pi\,\kappa_2$$

The total change of energy in the field at these points is therefore the difference between the loss and gain, and as this was caused through a motion over a space of 2 centimeters, the average force (equals energy ÷ distance moved) is

$$2\,[(D_3^2/8\,\pi\,\kappa_2 - D_1^2/8\,\pi\,\kappa) - (D_3^2/8\,\pi\,\kappa - D_1^2/8\,\pi\,\kappa_1)]$$

Suppose we have two plates, each 10 square centimeters in area and 1 centimeter apart, each plate charged with a quantity of electricity Q, the sign of the one quantity being + and that of the other —. Then D equals $4\,\pi\,Q/10$, and the energy (supposing the lines not to spread but to move straight from one plate to the other) per cubic centimeter of the space between the plates (which are supposed parallel to one another) is $D^2/8\,\pi\,\kappa$. If now one of the plates be moved back a distance $d\,l$, there will now be an additional volume of space between the plates of $10 \times d\,l$ square centimeters. If the charge remains the same, the same number of lines pass across each square centimeter of

the intervening space as before, and the energy per cubic centimeter is the same as before. But there is now a volume of $1 + d\,l$ cubic centimeters between each corresponding square centimeter of area of the plates, and the energy has therefore increased by $D^2\,d\,l/8\,\pi\,\kappa$ for each square centimeter of surface. And this increase is due to a motion $d\,l$, so the force is $D^2\,d\,l/8\,\pi\,\kappa \div d\,l$, or $D^2/8\,\pi\,\kappa$, per square centimeter of the plates. The total force acting to pull the plates together is therefore $10\,D^2/8\,\pi\,\kappa$.

Suppose next that the two charged plates are fixed and a sheet of glass 1 centimeter thick and 10 square centimeters in area is slid in between them, the charge remaining constant. The energy in the space between the plates was originally, if they were separated by air, $10\,D^2/8\,\pi\,\kappa_1$. It is now $10\,D^2/8\,\pi\,\kappa$. Since κ for glass is greater than κ_1 for air (the latter being 1), the energy of the whole system, when the glass is between the conducting plates, is less than it was previously. Consequently the glass plate will tend to slide in of its own accord. If it has to move through a space of 5 centimeters to do this, the average force tending to move it will be

$$10\,(D^2/8\,\pi\,\kappa_1 - D^2/8\,\pi\,\kappa) \div 5 \text{ equals } 2\,(D^2 - D^2/\kappa)/8\,\pi.$$

This amount of energy is withdrawn from the dielectric and changed into mechanical energy through the motion of the glass plate. If we fasten a string to the glass plate it may pull up a weight and so store the energy in the form of gravitational energy. If we simply allow the glass plate to swing, it takes on a velocity and the energy becomes energy of inertia, which gradually fritters itself away, if there be friction, into heat.

As another case, suppose the voltage to be kept constant. The original energy per cubic centimeter was $D^2/8\,\pi$, equals $F\,D/8\,\pi$. The energy after the movement of the plate is $D_1^2/8\,\pi\,\kappa = F\,D_1/8\,\pi$, for since the voltage has been kept constant and κ has increased and $D = \kappa\,F$, D must have increased to some other value, D_1. The difference of energy per cubic centimeter is therefore

$$F\,(D_1 - D)/8\,\pi.$$

But work has now been done in two ways, first by bringing fresh electricity on to the plates of the condenser, and secondly in the movement of the plate of glass. The former amount is equal to $F(D_1 - D) / 4\pi$, for quantity of electricity $\times$ voltage equals energy, and in this case the quantity is brought up to a constant potential and not, as when the condenser was first charged, to a potential gradually rising from zero to F, and whose average value was therefore 1/2 F.

But $F(D_1 - D) / 4\pi$ is greater than $F(D_1 - D)\ 8\pi$, and the difference, $F(D_1 - D) / 8\pi$, must have been spent on the motion of the glass plate. Since there are 10 cubic centimeters, the total so spent will be $10\ F(D_1 - D) / 8\pi$, and if the amount of motion is as before 5 centimeters, the average force will be $2\ F(D_1 - D) / 8\pi$.

Since $D = \kappa F$, and $\kappa =$ unity in the case of air, this formula reduces to $2\ (D_1^2 - D^2 / \kappa) \div 8\pi$, as before.

We thus see that the force acting to suck in the glass plate is the same whether the charge or the voltage is kept constant, but that in the former case the energy of the whole system is lowered by an amount $10\ (D_1^2 - D^2 / k)\ 8\pi$, whilst in the latter case it is increased by the same amount. It is for this reason that twice that amount had to be spent in bringing the additional charge up to the given potential.

[*To be continued.*]

BOOK NOTICES.

The Rise and Development of the Liquefaction of Gases. By Willett L. Hardin, Ph.D., Harrison Senior Fellow in Chemistry in the University of Pennsylvania. New York: The Macmillan Company. 1899. John Wanamaker, Philadelphia. (Price, $1.50.)

The author has given us in convenient form the important data bearing on the history of the subject of the liquefaction of gases, which are scattered through the periodical literature of the past thirty years. The scientific investigator of the subject and the inventor who is chiefly interested in the practical applications of liquefied gases will find Dr. Hardin's work equally serviceable. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 16, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1900.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 375 members and visitors.

Additions to membership since last report, 18.

Dr. A. E. Kennelly, Messrs. Carl Hering, Louis E Levy and W. C. L. Eglin were named as delegates to represent the Institute at the various scientific and technical congresses to be held in connection with the Paris Exposition.

Prof. Arthur J. Rowland gave a historical sketch of the various methods of incandescent lighting. Mr. George S. Barrows supplemented the remarks by Professor Rowland with an account of the latest improvements in the art, used by the Welsbach Company, and illustrated the subject by exhibiting several improved forms of the Welsbach mantle and burners, and with a series of lantern slides, showing the various steps in the manufacture of the Welsbach mantles.

Mr. Moriz Burger, of New York, gave a description of the Burger and Ostergren coil machine for liquefying air, and gave an account of the recent researches of Prof. Raoul Pictet in the separation of air into its constituent parts, and of the industrial uses of oxygen, nitrogen and carbon dioxide. This communication was illustrated by numerous experiments.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 2, 1900.*]

MR. HENRY R. HEYL in the chair.

The following reports were adopted :

National Export Exposition.—Exhibit of the U. S. Geological Survey. [Referred by the Bureau of Awards.]

Report.—For the reasons set forth in the following report, the sub-committee charged with this investigation recommends the grant of the Elliott Cresson Medal to the U. S. Geological Survey, viz.:

ABSTRACT.—"The large space occupied by the U. S. Geological Survey is richly and instructively filled with the products of the industry of this useful branch of the Government.

"The exhibits of the Survey comprise maps, photographs, publications and a typical series of rocks.

"I. The maps are (*a*) geographical ; (*b*) topographical, in contour curves or in relief, and (*c*) geological and statistical, *i. e.*, colored to represent the geological structure and the distribution of deposits of economical value. Besides the above are vertical sections where these seem of advantage to the comprehension of the subject.

"In all these maps the best methods and workmanship of modern cartography have been employed. For the topography, the system of contour curves, displayed in the large atlas maps of the Hayden survey, retains in the later maps an equal excellence of finish, but represents a greater accuracy of field work.

"There are five specimens of relief maps reproducing (1) the United States on a scale of 1 inch to 12 miles horizontally, and to 1·2 miles vertically, the vertical scale being exaggerated to ten times the horizontal for the purpose of better marking the relief; (2) the Atlanta-Chattanooga district; (3) Nebraska; (4) Tennessee; (5) Connecticut. These models show the perfection to which Prof. J. P. Lesley brought this kind of work in the late Second Geological Survey of Pennsylvania.

"A photograph of one of these models, appropriately illuminated, illustrates the device of Professor Lesley for distributing the comprehensive knowledge imparted by these instructive plans as widely as the printed pages of the reports.

"In all these maps the accuracy of registration of the several parts upon each other, as well as the constancy of the coloring of the different sections, are worthy of special attention, because they indicate the successful solution of two of the most difficult problems in section map-making.

"A large lithographic press in another part of the building is in active operation, under the direction of the U. S. Geological Survey.

"II. The photographs of the U. S. Geological Survey have long been famous. In no other national geological survey have photographic illustration been so lavishly and judiciously employed to illustrate the text of the technical studies. But beside this purpose, the splendid colored transparencies of Mr. J. K. Hiller, presenting in brilliant natural colors the Grand Cañon of the Yellowstone Park, and another typical Western view, are in the front rank of their branch of the photographic art.

"III. The publications of the Bulletins and Annual Reports of the Geological Survey, among which are included the statistical record of the mineral industry down to the end of the year 1898, exhibit the information given to the people since 1880. The only criticism to be made is the arbitrary adoption of this last date, as if it were the commencement of national geological work here, though, of course, this choice could be justified by the present title of the service. In point of fact, however, the publications which first called the attention of the world to the admirable work this country was doing in the systematic study of her resources, and which made possible the organization of the present, were issued for ten years anterior to 1880.

"IV. Following the example first set in Germany, the Survey has prepared a series of 150 specimens of typical rocks, whose names recur frequently in the reports. The value of such collections cannot be overestimated. They make clear the descriptions of complicated geological conditions, and put an effective check upon that natural enemy of geological science, the petrographic name-maker.

"In the sense and for the purpose of a demonstration to the public of the usefulness and industry of a great public work for which the public pays, this exhibit is deserving of the highest praise, and your committee recommends the Silver Medal and a diploma, the highest award within its gift.

"It recommends in addition the reference of this exhibit to the Committee of Science and the Arts of the Franklin Institute for further investigation, with a view to special reward of merit." [*Sub-Committee*, Theo. D. Rand, Chairman; Persifor Frazer.]

National Export Exposition.—Laird, Schober & Co.'s Exhibit. Boots and Shoes. [Referred by the Bureau of Awards.]

ABSTRACT.—For quality of material, beauty of design, expert workmanship and proper proportions of the products of these manufacturers the award is made of the Edward Longstreth Medal of Merit. [*Sub-Committee*, J. Ware Jones, Chairman; Howard L. Townsend, Wm. C. Benkert.]

National Export Exposition.—Exhibit of A. J. Holman & Co. Subject, Bibles.

ABSTRACT.—The report of the Investigating Committee, after due re-examination of the exhibit of A. J. Holman & Co., of Philadelphia, is substantially as follows:

"One of these productions, however, merits the special consideration of your body, namely, the edition known as the 'Linear Parallel Bible.' This work presents the varying passages of the King James and the Revised Version of the Scriptures in a manner at once original and effective. The versions are placed in juxtaposition, in close parallel lines, the older rendering in the upper and the revised version in the lower line, both printed in a plain and clear type combination, which affords the reader at a glance a direct comparison of the two renderings, including all the variæ, from changes of the text to the minutest detail of the changes in punctuation, many of the latter being as important as those of the text.

"For students especially this innovation is of marked value, as the ordinary method of presenting variations of this character by parallel columns or marginal notations is extremely taxing both to the eye and to the mind of the investigator.

"The mechanical execution of this edition is such as to make it an example of the most advanced art in book-making, 1,000 pages being comprised in a thickness of only ⅝ of an inch, while with this extreme thinness the paper combines the requisite qualities of strength and opacity of texture.

"In recognition of the originality of design in this work, and of its technical excellence, your sub-committee recommends that the Franklin Institute award to Messrs. A. J. Holman & Co. the Edward Longstreth Medal of Merit." [*Sub-Committee*, Louis E. Levy, Chairman; John R. McFetridge, Stephen Greene, J. L. Shoemaker, F. Oldach.]

National Export Exposition.—Exhibit of the Pencoyd Iron Works, Pencoyd, Pa. [Referred by the Bureau of Awards.]

This report is reserved for publication in full.

The award of the Elliott Cresson Medal is recommended to the exhibitors for remarkable progress exhibited in bridge and other structural engineering. [*Sub-Committee*, Thos. P. Conard, Chairman; H. F. J. Porter, Joseph Hartshorne, Harrison Souder, Jacob Y. McConnell.]

National Export Exposition.—Improvements in Filing Cabinets. Wm. H. Tucker, Newark, N. J. Report:

ABSTRACT.—This application has reference to certain improvements in Filing Cabinets invented by Wm. H. Tucker, of Newark, N. J., including a

support for bill file holder, patented December 18, 1883 (No. 290,497); a file box, patented on same date (No. 290,498); a system of indexes, for use in connection with appliances for filing documents, patented July 14, 1891 (No. 455,-807), and also to certain improvements in bill files and card indexes, invented by Emil J. Bein, of Newark, N. J., patented July 4, 1899 (No. 627,967), and August 14, 1899 (No. 631,772).

These improvements are embodied in the Letter and Document Files and Card Index Cabinets manufactured by the Tucker File Company, of Newark, N. J., and formed the subject-matter of an investigation and report by the undersigned, acting as a Jury of Awards at the National Export Exposition of 1899 (see Appendix).

To that report, which is hereby specifically confirmed, your sub committee takes this occasion to add a consideration of the Index System invented by Wm. H. Tucker, which, while quite adapted for use in connection with any document file whatever, is given a marked degree of efficiency by the several carefully designed devices applied to the Tucker Cabinets, as noted in the former report already referred to. These Letter and Document Files, as thus completed with a comprehensive index, together with the ingeniously-contrived card-index cabinets, afford a means and a system of filing documents for ready reference and easy access which appears to leave nothing to be desired.

In recognition of the improvements effected in the design and construction of Files for Documents, and in the system of indexing the latter, your sub-committee recommends the award to William H. Tucker of the Edward Longstreth Medal of Merit; and in recognition of improvements in Letter File Clamps and Index-card Holders, your sub-committee recommends the award to Emil J. Bein of a Certificate of Merit. [*Sub-Committee*, Louis E. Levy, Chairman; F. Oldach, J. L. Shoemaker.]

As the action of the Bureau of Awards is referred to specifically by the sub-committee for information respecting the reasons for its award, the report in question is herewith reproduced:

APPENDIX.

COPY OF REPORT OF THE JURY OF AWARDS, N. E. E., 1899.

The exhibit of File Cabinets made by the Tucker File Company, of Newark, N. J., presents a series of novel and highly convenient appliances. Notable among these is a clamping device by which the papers filed in the receptacles are compressed so as to utilize space to the utmost and to maintain the papers in their original compactness, while at the same time the device is so arranged as to permit the contents of the file to be completely freed for easy access at any point. The automatic suspension device by which the file is held in place for convenient examination is thoroughly efficient. The arrangement of a supporting slide for the card index files, and the devices for holding and conveniently freeing the index cards, are worthy of special commendation.

The thoroughness with which the details of these File Cabinets have been wrought out is fully equalled by the mechanical excellence of their construction, and, in view of these aspects of the exhibit, the Committee of Judges recommend the award of the Exhibition Silver Medal and Diploma of the

Franklin Institute to the exhibitors, and also the reference of these constructions to the Institute's Committee on Science and the Arts for due consideration of that body.

(Signed) LOUIS E. LEVY, *Chairman.*
JOHN R. MCFETRIDGE,
STEPHEN GREENE,
FREDERICK OLDACH,
J. L. SHOEMAKER.

Basin System.—C. L. Riker, Newburgh, N. Y.

ABSTRACT.—This invention consists of a complete washstand with fittings, containing many desirable features, being a self-contained fixture with a novel application of the siphon single-pipe waste. The report finds that the system in respect of design of details, mechanical construction and workmanship is worthy of commendation, and awards the Edward Longstreth Medal of Merit to the inventor. [*Sub-Committee*, Frank P. Brown, Chairman ; John E. Evanson, Wm. Copeland Furber, John Joyce.]

Variable-Speed Countershaft.—Milton O. Reeves, Columbus, Ind.

(Referred back to sub-committee for amendment.)

Passed first reading:

Machine for Tangible Writing for Touch Reading.—Wm. B. Wait, New York City.

National Export Exposition.—The Welsbach System of Lighting. Welsbach Commercial Company, Philadelphia.

National Export Exposition.—International Incandescent Light Company's Lamp. International Incandescent Lamp Company, Philadelphia.

National Export Exposition.—Improvements in Carriages and Wagons. Chas. S. Caffrey Company, Philadelphia.

Lever and Ratch Attachment.—Waterbury Tool Company, Waterbury, Conn.

(These were held over for one month.)

Method of Obtaining Energy for Automobiles.—John Stolze, Reading, Pa.

W.

SECTIONS.

ELECTRICAL SECTION.—*Stated Meeting*, held Tuesday, April 24th. Prof. W. S. Franklin in the chair.

The paper of the evening was read by Mr. J. Franklin Stevens, of Philadelphia. Subject, "Electrical Instruments."

The paper sketched briefly the development of the art embodied in the manufacture of commercial indicating instruments, stating the most desirable qualities of modern types. The systems most commonly employed were each briefly discussed, principle of operation explained and their limitations described. Stress was laid on the fact that there is no type of instrument which is absolutely universal, and the general rules for selecting the most desirable type for any particular class of measurement were set forth. A number of details connected with the manufacture of various types of instruments were given and some special types of instruments described in detail. The deriva-

tion of fundamental electrical units was dwelt upon and the relations between primary and secondary standards described.

RICHARD L. BINDER,
Secretary.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, May 3d. Dr. Henry Leffmann in the chair.

Mr. Lyman F. Kebler gave the Section an account of a series of examinations he had made of commercial samples of gold chloride in which he had discovered a considerable difference in the quality of the various brands on the market. He said that, taking an estimated quantity of 100 ounces, the difference in actual value between the best and the worst would amount to over $150, and that between these two there were all grades of value.

Dr. Henry Leffmann quoted portions of a paper by William James Russell, recently presented to the Royal Institution of Great Britain, relating to pictures produced in the dark, in which the theory is advanced that the action is due to the formation of hydrogen dioxide.

The meeting was closed by an exhibition of lantern slides of the path of the coming eclipse of the sun, and of views of the dam on the Colorado River at Austin, Tex.

F. W. SAWYER,
Secretary.

PHYSICAL AND ASTRONOMICAL SECTION.—*Stated Meeting*, held Friday, May 4th. Dr. A. S. Kennelly in the chair.

The paper of Mr. H. M. Watts, read at the April meeting, on "The Proper Organization of the Modern State Weather Service," was the special subject of the evening.

Mr. Watts' remarks were informal. He exhibited two reports, one, that of the Maryland State Weather Bureau, and the other our own, which was an unbound pamphlet, very valuable, as far as it went, but not to be compared with that of Maryland. The Maryland service had an appropriation of $2,000 per year for its maintenance, which had been granted with the proviso that none of it should be spent for salaries. As a consequence, it had all been used upon the publication, which was composed of monographs on meteorology, physiography and kindred subjects, written by specialists, the collected observations of the United States Weather Bureau having been used as data. Mr. Watts thought that the adoption of something similar in this State would prove of great value, and suggested that the Section take steps to interest other institutions of learning throughout the State in the matter, with the view of getting an appropriation of, say $3,000, and organizing a bureau modeled so far as conditions would admit on that of Maryland. The subject was discussed by Messrs. Dey and Towusend.

On motion of Dr. Wahl, the President was authorized to appoint a committee to confer with the various technical institutions throughout the State, with a view to carrying out Mr. Watts' suggestions.

The President announced as the next subject "The Consideration of the Subject of Making Observations and Records of the Total Solar Eclipse of May 28th."

Dr. Wahl, Mr. Weinrich, Mr. Watts and others took part in the discussion which followed.

The President stated that the Section, in conjunction with the Section of Photography and Microscopy, had arranged to issue the following joint bulletin:

For the benefit of those who may not be familiar with modern methods of observing and recording solar eclipses, but who intend to observe the eclipse of May 28, 1900, the following suggestions have been prepared, with the aid of information contained in a supplement to the *American Ephemeris* (*Nautical Almanac*) for 1900, as published by the Bureau of Equipment of Washington. Additional information has also been obtained personally from Professor Doolittle, of the Flower Observatory.

Amateur observers, and those not provided with elaborate astronomical apparatus, may be able to furnish valuable data from their observations in the following four ways:

(1) Sketches of the corona with the naked eye.

(2) Observations of such moon's shadow bands as may be observed.

(3) Observations of the times of contacts.

(4) Photographs of the corona.

Useful sketches can be made with the naked eye, but they must be limited to outlines or particular features, if satisfactory records are to be obtained. Co-operation of several sketchers is advantageous. Sketchers should avoid fatiguing the eye by too frequent observations of the eclipse while partial, and should refrain from making any observation for the five minutes preceding totality.

The following directions are given for sketching: Upon a sheet of paper, say 9 x 12 inches, a black disc 1¼ inches in diameter is drawn, with a series of projecting radii at angles of 30°. The positions of various parts of the corona as seen against the sky are best indicated by reference to a vertical line obtained by mounting a plumb-line so that it is seen over the moon's center. The diagram upon which the drawing is to be made is placed on any convenient support, so that the lines marked "top" and "bottom" are in the plane of the plumb-line, the top corresponding to the top of the string. The members of the sketching corps should do some preliminary practice, each sketching a particular quadrant from a drawing of a corona placed at the angular height of the sun. The time of practice in drawing should be a little less than the actual duration of totality. White chalk on purplish-blue paper gives excellent results.

In regard to the fourth or photographic method, the results of the East Indian eclipse expedition in 1898 have shown that valuable photographs may be obtained with instruments of moderate dimensions. Among the best results on that occasion were those obtained by amateurs, one with a Dallmeyer stigmatic lens, and one with a Dallmeyer rapid rectilinear of 2·125 inches aperture, only the back lens being used, which gave an equivalent focus of 32·5 inches.

Plates of ordinary sensitiveness (which are more convenient than extraordinarily rapid ones) will require an exposure of from one to two seconds (referred to $\frac{f}{a} = 16$). The camera should be set by bringing a well-defined object, distant about half a mile, into sharp focus at the center of the plate. The actual image of the sun will be a small part of the field, for the focal

length of the lens in inches will be approximately the diameter of the sun's image in hundredths of an inch. Negatives must not be retouched or otherwise altered. Driving apparatus for the camera is not necessary, very good results having been obtained with common instruments, but, of course, photographs taken with cameras provided with a driving clock or other device for keeping the image stationary on the plate are most useful.

When $\frac{\text{Equivalent Focus}}{\text{Aperture}}$ or $\frac{f}{a}$ is not greater than 15, and the focal length is not greater than 5 feet, the blurring of the image in a stationary camera during an exposure of $\frac{1}{2}$ second is only $\frac{1}{400}$ of an inch; practically imperceptible.

It is of the highest importance that the camera be rigidly mounted. Plates should be so marked as to enable the operator to determine after development which was the top of plate as exposed.

The total eclipse of the 28th of May commences on the earth at approximately 15 minutes past 6 A.M., Eastern time of the seventy-fifth meridian, and ends at about 33 minutes past 10 o'clock A.M. of the same Eastern time. During this time the moon's shadow will have passed nearly half way round the northern hemisphere, and the period of totality at any one point in the United States is but little over one minute, being about 72 seconds in New Orleans and about 90 seconds near Norfolk, Va. The eclipse which is visible in the early morning in the United States is visible in Europe and in Northern Africa some two hours later in actual time, and consequently photographs of the corona obtained in the United States will be comparable with those obtained on the other side of the Atlantic two hours later, which may possibly lead to valuable results. The path of totality is central over New Orleans about 8 A.M., local time, and passes northeasterly across the United States, passing near to Greenville, Ala.; Union Springs, Ala.; Talbot, Ga.; Newberry, S. C.; Lancaster, S. C.; Rockingham, Edgecombe, Gatesville, N. C., and passes into the Atlantic about seventeen miles south of Norfolk, Va. Although this is the central line, totality for a diminished period will be visible at any point within about twenty-five miles on either side of this line. Near Norfolk the totality will take place about 9 A.M. Eastern time (8.52 A.M.). W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, May 9th. Mr. Joseph Richards in the chair.

The meeting was devoted to a continuation of the discussion of the paper of Mr. Kreuzpointner, which was left unfinished at the previous meeting.

The principal speaker was Mr. A. E. Outerbridge, Jr., who proceeded with the consideration of the subject in so far as it related to cast iron.

Mr. Wm. R. Webster and Prof. Henry M. Howe, of Columbia University, New York, contributed to the discussion of Mr. Outerbridge's remarks, and the further consideration of the subject was postponed.

Owing to the lateness of the hour, the paper presented by Mr. B. S. Lyman, on "Underground Water," was read by title, and referred to the Committee on Publication.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, May 10th. Prof. John F. Rowland, Jr., President, in the chair.

The paper of the evening was read by Mr James S. Merritt, on "Expanded Metal, with Incidental Reference to its Application in Concrete Construction."

The speaker said in substance:

"Expanded metal has become much more widely used than was originally anticipated by the inventor, J. F. Golding, of Chicago. He intended to make window screens, trellis work, etc., and called the material 'slashed metallic screening,' afterward 'expanded metal' (French, 'metal deployé,' German, 'streckmetal')."

The speaker gave a description of the original method of cutting expanded metal and of the improvement introduced by Mr. Golding, in 1894, which permits the use of much heavier steel than formerly. The cutting and the opening out of expanded metal are done simultaneously. No steel is wasted, as there are no pieces punched out. The finished sheets are from three to eight times as large as the original sheets of steel. The process requires good stock and careful adjustment of the shear blades, which must be kept sharp. Numerous other operations, such as annealing, pickling, etc., are necessary for a perfect product.

The principal use of expanded metal at the present day is in fireproof construction of buildings and as a "binder" in concrete structures of all kinds. The extent of its use is shown by the fact that over 9,000,000 square feet, or 200 acres of various grades of expanded metal were used in the buildings of the Paris Exposition for floors, exterior walls, etc. This is a little greater than the area bounded by the Delaware and Schuylkill Rivers, Market and Sansom Streets. There is scarcely a prominent building in the United States which has been completed during the last ten years that does not contain a considerable quantity of expanded metal. Examples: Library of Congress, Washington; Carnegie Library, Pittsburgh; Free Library, Boston; City Hall, Philadelphia; Masonic Temple, Boston. Many illustrations were shown of the details of such work. Expanded metal is used by the Bell Telephone Company, of Philadelphia, in a sewer passing through their large manhole at Seventeenth and Filbert Streets. By the combination of expanded metal with concrete in such a way that the steel resists the tensile stresses, concrete can be used in many fields from which it has hitherto been debarred on account of its low tensile strength. Engineers are using it all over the world to reinforce concrete in the construction of bridges, piers, sea walls, docks, etc. Expanded metal is also used for many curious purposes, such as riffles in placer gold mining, brake shoes, bird-cages, doormats, etc.

DANIEL EPPELSHEIMER, JR.,
Secretary.

CHEMICAL SECTION.—*Stated Meeting*, held Tuesday, May 15, 1900. Dr. W. J. Williams, President, in the chair.

The paper of the evening was read by Dr. S. P. Sadtler. Subject, "A Historical Review of the Subject of Mineral Tanning."

The speaker gave an interesting address covering the application of alum, iron and chrome salts and formaldehyde for tanning skins, and illustrated

the subject by the exhibition of a number of specimens of each species of tanning.

(Referred for publication.)

WM. E. RIDENOUR,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Tuesday, May 22d. Mr. Joseph Richards in the chair. Twenty members present.

The Section voted to change the evening of the stated meeting from the fourth Tuesday to the third Thursday of each month, except in July and August.

Mr. C. H. Bedell, of Philadelphia, presented a communication on "An Electrical Revolution Indicator, and the Pfatischer Electrical Steering Gear," which was discussed by Professors Hoadley and Stine, and referred for publication. W.

CLOSING EXERCISES OF THE SCHOOL OF NAVAL ARCHITECTURE.

The closing exercises of the School of Naval Architecture were held in the lecture room of the Institute on Friday evening, May 18th, at 8 o'clock.

Mr. James Christie presided.

Brief addresses appropriate to the occasion were made by the chairman; Dr. Wahl, Chairman of the Committee on Instruction, and Mr. Alex. J. Maclean, Director of the School.

The Director stated that thirty eight pupils had been enrolled in the first session of the school, and gave an encouraging account of the work of the students and of the future prospects of the school.

The Director of the school made the following report:

"The Franklin Institute School of Naval Architecture commenced on Friday evening, October 20, 1899, with twelve students, and at each successive Friday evening received increments to registration until the maximum thirty-eight was reached early in January, 1900. During this term of twenty-seven weeks the average attendance has been sixteen.

"The course of instruction in the several branches of naval architecture was followed on parallel lines, embracing more than one-half of the synopsis issued at commencement. Blue-prints of details of construction of the different classes of vessels, both for the naval and mercantile marine, were lent to the students, from which they were able to make sketches applicable to lectures given. Homework, in the form of calculations similar to those described and worked in classroom, was performed by the students, the majority of the students showing marked ability."

Prizes, consisting of cases of draughting instruments and technical books, were distributed on behalf of the donors, Messrs. Chas. H. Cramp, Clement A. Griscom, Lewis Nixon and the Director of the School.

The recipients of the prizes were: Fred. A. Coolidge, Wilmington, Del.; Henry T. Darlington, West Chester, Pa.; James A. Kelly, Chester, Pa., and Wm. H. Balls, Philadelphia. W.

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